ENTOMON

CONTENTS

ENTOMON

SUBSCRIPTION RATES

Species Complex, Population Density and Dominance Structure of Aphidophagous Syrphids in Cowpea Ecosystem

Sunil Joshi*, Chandish R. Ballal and N. S. Rao

Project Directorate of Biological Control, Post Bag No. 2491, H. A. Farm Post, Bellary Road, Bangalore 560024, Karnataka, India
Email: root@pdblc.kar.nic.in

ABSTRACT: Six species viz. *Paragus serratus* (Fabricius), *Paragus yerburiensis* Stuckenberg, *Ischiodon scutellaris* (Fabricius), *Dideopsis aegrota* (Fabricius), *Betasyrphus linga* Ghorpade and *Betasyrphus fletcheri* Ghorpade were identified to form the predatory syrphid complex of *Aphis craccivora* Koch in Bangalore conditions. The seasonal abundance of these species showed remarkable variations. *A. craccivora* was found to be preyed upon by three species of syrphids in summer and five species in kharif season of 1996 but by three and four species during summer and kharif, respectively, during 1997. Population density and dominance structure of these species also underwent seasonal variation. *I. scutellaris* was dominant throughout the crop seasons during both the years. *B. fletcheri* was recorded only during kharif of 1996 and *B. linga* was found to feed on *A. craccivora* infesting pigeonpea and gliricidia during January–March. Although one or the other species remained active in the field throughout the crop season, syrphid larvae were relatively more abundant during the last two weeks of April and first two weeks of May. The study demonstrated a prey-dependent syrphid predator growth, often failing to reach ideal predator-prey ratio of 1 : 100, emphasizing the need for aphid control by way of augmentation of syrphid predators. © 1999 Association for Advancement of Entomology

KEYWORDS: *Aphis craccivora*, cowpea ecosystem, predatory syrphids, species complex

INTRODUCTION

Cowpea aphid *Aphis craccivora* Koch is one of the most common major pests of cowpea (*Vigna unguiculata* (L.) Walp.) (Bernado, 1969; Kayumbo, 1975; Saxena, 1978; Singh, 1979; Singh and van Emden, 1979; Singh and Jackai, 1984) Infestation begins in the seedling stage, small populations do little direct damage, but feeding by large populations causes distortion of the leaves and the plants become stunted with poor nodulation of the root system (Singh and van Emden, 1979). The most serious damage is caused by transmission of virus diseases (Bock and Conti, 1974).

*Corresponding author

Recent records on rapid change in the susceptibility level of *A. craccivora* to synthetic pyrethroids and other pesticides (Dhingra, 1993) have led to investigations on the effectiveness of biocontrol agents in aphid management. The aphidophagous syrphids, which occupy quite a remarkable place among naturally occurring biocontrol agents of aphids (Agarwala *et al.*, 1984), were observed to explore their diversity and population distribution with reference to cowpea ecosystem in Bangalore, Karnataka.

MATERIALS AND METHODS

The experiment was carried out by planting C 152 variety of cowpea in a plot (5 × 4 meters). Regular fertilizer and irrigation practices were followed. The crop was observed for appearance of aphids. After recording the first appearance of aphids, observations were recorded every week, on ten randomly selected plants. In the experimental plot, no spraying, plucking of leaves or pods or removal of aphid was done. On each observation date, number of aphids present on each plant and different species of syrphids were recorded. Aphid count was made by following the method devised by Srikanth and Lakkundi (1990).

Data so obtained were used for determining the species complex and population density of syrphids. Syrphid larvae collected during the observations were reared in the laboratory on cowpea aphid till the emergence of adults and the data were used to determine the dominance structure by working out the percentage of different syrphid species in the total population on weekly basis. The egg stage was not sampled since it was not possible to locate and separate them specieswise in the aphid colony. Similarly, the pupal stage was also not sampled since most of the species pupated in the soil or debris. The observations were recorded during summer and kharif seasons of 1996 and 1997. With a view to determine the relationship between fluctuating natural populations of the cowpea aphid and its syrphid predators, the data pertaining to their populations recorded during determination of species complexity and population density were used. Their number per ten plants recorded on weekly basis were taken into consideration for working out correlation co-efficients between the population of aphid, individual and total syrphids and predator-prey ratio.

RESULTS AND DISCUSSION

In both summer and kharif, six species, viz. *Paragus serratus* (Fabricius), *P. yerburiensis* Stuckenberg, *Ischiodon scutellaris* (Fabricius), *Dideopsis aegrota* (Fabricius), *Betasyrphus linga* Ghorpade and *B. fletcheri* Ghorpade were identified to form the syrphid complex predating on *A. craccivora* in cowpea ecosystem in and around Bangalore, Karnataka. All species, except *B. fletcheri* and *B. linga*, have been reported earlier from India (Ghorpade, 1981).

In the first year (1996), during both the crop seasons, number of species involved in suppressing aphids was found to undergo remarkable variation (Table 1 & 2). During March–May, only three species existed in nature, while during August–October five species were recorded. In the beginning only one species was involved in predation
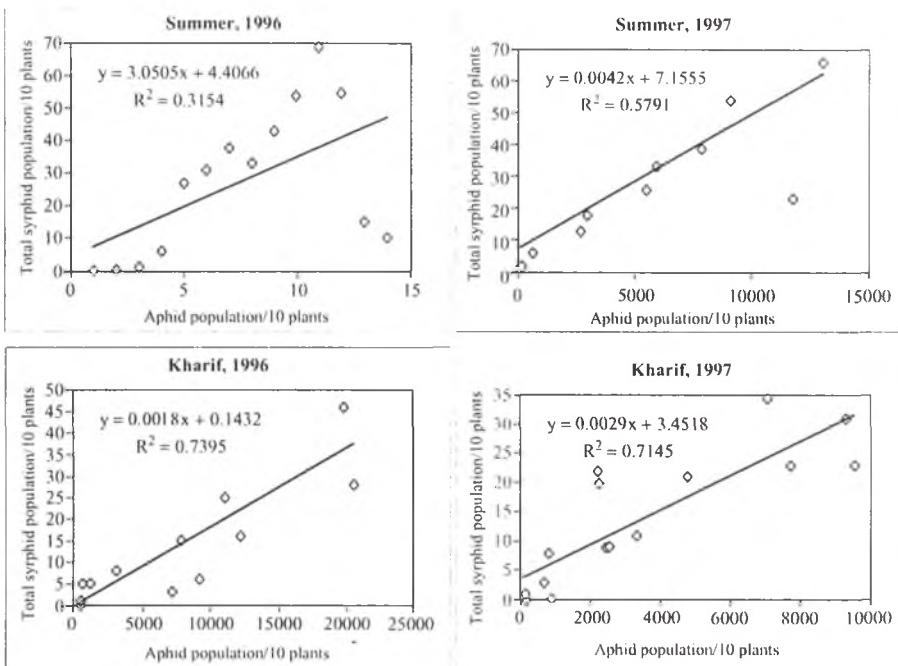
FIGURE 1. Relationship of aphid population and total syrphaid population during summer and kharif season of 1996 and 1997.

but its number continued increasing till the end of the season when as many as three and five species existed in summer and kharif season, respectively.

Out of the six species of syrphids, *P. yerburiensis* was the earliest to appear in both the seasons. It remained active till the end in summer but in kharif it was active till the end of September only. Its population ranged from 1 to 19 larvae per ten plants with a peak in the third week of April in summer and 1 to 4 larvae per ten plants with a peak in the first week of September in kharif. *P. serratus* was the second species of syrphid to appear, followed by *I. scutellaris*. *I. scutellaris* remained active till the end of both the crop seasons and maintained a relatively higher population density, ranging from 1 to 53 and 3 to 16 larvae per ten plants with peaks in the first week of May and fourth week of September when it constituted 76.81 and 34.78 percent of syrphid population in summer and kharif respectively. But as regards the dominance structure, its share in the community reached highest level, that is 90 percent and 100 percent, at the end of summer and kharif, respectively.

Among the remaining species, *P. yerburiensis* occupied the first position during second to fourth week of March and first three weeks of April during summer and second week of August during kharif, while *P. serratus* hold second position during third week of March and first two weeks of April. During fifth week of March, *P. serratus* and *I. scutellaris* contributed equally (35.48% each), while in the first week

TABLE 1. Species complexity, population density and dominance structure of syrphids on *A. craccivora* Koch on cowpea during summer 1996

Month/week		Mean number of syrphid larvae per ten plants						Number of species recorded	Number of syrphid larvae per plant	Total number of aphids per plant	Predator: Prey ratio
		A	B	C	D	E	F				
March	I	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0	0	16.00	-
	II	1(100)	0(0)	0(0)	0(0)	0(0)	0(0)	1	0.1	19.00	1:190
	III	3(50.00)	2(33.33)	1(16.66)	0(0)	0(0)	0(0)	3	0.6	52.80	1:88
	IV	12(44.44)	6(22.22)	9(33.33)	0(0)	0(0)	0(0)	3	2.7	140.40	1:52
	V	9(29.03)	11(35.48)	11(35.48)	0(0)	0(0)	0(0)	3	3.1	517.70	1:167
April	I	16(42.11)	14(36.84)	8(21.05)	0(0)	0(0)	0(0)	3	3.8	786.60	1:207
	II	12(36.36)	11(33.33)	10(30.30)	0(0)	0(0)	0(0)	3	3.3	1296.90	1:393
	III	19(44.19)	10(23.26)	14(32.56)	0(0)	0(0)	0(0)	3	4.3	1384.60	1:322
	IV	18(33.33)	9(16.66)	27(50.00)	0(0)	0(0)	0(0)	3	5.4	1387.80	1:257
May	I	9(13.04)	7(10.14)	43(76.81)	0(0)	0(0)	0(0)	3	6.9	2007.90	1:291
	II	3(5.45)	4(7.27)	48(87.27)	0(0)	0(0)	0(0)	3	5.5	2249.50	1:4093
	III	1(6.67)	2(13.33)	12(80.00)	0(0)	0(0)	0(0)	3	1.5	1789.50	1:119
	IV	1(10.00)	9(0)	9(90.00)	0(0)	0(0)	0(0)	3	1.0	891.00	1:891

Figures in parentheses indicate percent population composition of syrphids A-*P. yerburiensis*, B-*P. serratus*, C-*I. scutellaris*, D-*D. aegrota*, E-*B. fletcheri*, F-*B. linga*

TABLE 2. Species complexity, population density and dominance structure of syrphids on *A. craccivora* Koch on cowpea during kharif 1996

Month/week		Mean number of syrphid larvae per ten plants						Number of species recorded	Number of syrphid larvae per plant	Total number of aphids per plant	Predator: Prey ratio
		A	B	C	D	E	F				
August	I	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0	0.0	39.00	-
	II	1(100)	0(0)	0(0)	0(0)	0(0)	0(0)	1	0.1	48.00	1:480
	III	2(40.00)	0(0)	3(60.00)	0(0)	0(0)	0(0)	2	0.5	59.00	1:118
	IV	1(20.00)	1(20.00)	3(60.00)	0(0)	0(0)	0(0)	3	0.5	114.00	1:228
	V	3(37.50)	2(25.00)	3(37.50)	0(0)	0(0)	0(0)	3	0.8	308.00	1:385
September	I	4(26.66)	5(33.33)	6(40.00)	0(0)	0(0)	0(0)	3	1.5	789.00	1:526
	II	2(8.00)	6(24.00)	12(48.00)	5(20.00)	0(0)	0(0)	4	2.5	1102.50	1:441
	III	2(5.13)	8(20.15)	15(38.46)	11(28.21)	2(5.13)	0(0)	5	3.8	1314.80	1:346
	IV	1(2.17)	3(6.52)	16(34.78)	23(50.00)	3(6.52)	0(0)	5	4.6	1987.2	1:432
October	I	0(0)	1(3.57)	12(42.86)	9(32.14)	6(21.43)	0(0)	4	2.8	2052.40	1:733
	II	0(0)	0(0)	6(37.50)	7(43.75)	3(18.75)	0(0)	3	1.6	1217.60	1:761
	III	0(0)	0(0)	3(50.00)	3(50.00)	0(0)	0(0)	2	0.6	918.00	1:1530
	IV	0(0)	0(0)	3(100.00)	0(0)	0(0)	0(0)	1	0.3	720.00	1:2400

Figures in parentheses indicate percent population composition of syrphids A-*P. yerburiensis*, B-*P. serratus*, C-*I. scutellaris*, D-*D. aegrota*, E-*B. fletcheri*, F-*B. linga*

FIGURE 2. Relationship of aphid population and population of *Ischioden scutellaris* during summer and kharif season of 1998 and 1997.

of August *P. yerburiensis* contributed equally with *I. scutellaris* (37.50% each) to the field population of syrphids.

With regards to the relationship between the dominance structure of syrphid and growth stage of the crop, it was found that the peak *I. scutellaris* population coincided with pod formation which coincided with peak aphid population, while both the species of *Paragus* were major contributors during the vegetative growth.

Other species like *B. fletcheri* and *D. aegrota* were minor contributors and occurred only in kharif season and reached peak during fourth week of September and first week of October, when these contributed 50 and 21.43 percent to the syrphid community. *B. linga* occurred only on pigeonpea and gliricidia during January. As regards the dominance structure of syrphids during whole season, it was found that *I. scutellaris* dominated both during summer (50%) and kharif (42%) which was followed by *P. yerburiensis* (28%) and *D. aegrota* (30%) during summer and kharif, respectively (Fig. 2).

In 1997, the larval activity of syrphids started from the first week of March and second week of August during summer and kharif seasons, respectively (Table 3 & 4). During March–May, three species existed in nature, while during August–November only four species were recorded as against five species in Kharif season of 1996.

The peak larval counts of *P. yerburiensis*, *P. serratus* and *I. scutellaris* were

TABLE 3. Species complexity, population density and dominance structure of syrphids on A. *craccivora* Koch on cowpea during summer 1997

Month/week		Mean number of syrphid larvae per ten plants						Number of species recorded	Number of syrphid larvae per plant	Total number of aphids per plant	Predator: Prey ratio
		A	B	C	D	E	F				
March	I	1(100.00)	0(0)	0(0)	0(0)	0(0)	0(0)	1	0.1	7.90	1:79
	II	1(50.00)	1(50.00)	0(0)	0(0)	0(0)	0(0)	2	0.2	19.60	1:98
	III	4(66.66)	2(33.33)	0(0)	0(0)	0(0)	0(0)	2	0.6	66.60	1:111
	IV	15(65.21)	4(17.39)	4(17.39)	0(0)	0(0)	0(0)	3	2.3	1177.60	1:512
	V	8(30.76)	6(23.07)	12(46.25)	0(0)	0(0)	0(0)	3	2.6	553.80	1:213
April	I	14(35.89)	11(28.20)	14(35.89)	0(0)	0(0)	0(0)	3	3.9	791.70	1:203
	II	10(30.30)	13(39.39)	10(30.30)	0(0)	0(0)	0(0)	3	3.3	597.30	1:181
	III	21(38.88)	16(29.62)	17(31.48)	0(0)	0(0)	0(0)	3	5.4	912.60	1:169
	IV	19(32.75)	10(17.24)	29(50.00)	0(0)	0(0)	0(0)	3	5.8	591.60	1:102
May	I	10(15.15)	7(10.60)	49(74.24)	0(0)	0(0)	0(0)	3	6.6	1306.80	1:198
	II	9(13.84)	5(7.69)	51(78.46)	0(0)	0(0)	0(0)	3	6.5	721.50	1:111
	III	4(22.22)	1(5.55)	13(72.22)	0(0)	0(0)	0(0)	3	1.8	300.60	1:167
	IV	2(15.38)	0(0)	11(84.61)	0(0)	0(0)	0(0)	2	1.3	273.00	1:210

Figures in parentheses indicate percent population composition of syrphids A-*P. yerburiensis*, B-*P. serratus*, C-*I. scutellaris*, D-*D. aegrota*, E-*B. fletcheri*, F-*B. linga*

TABLE 4. Species complexity, population density and dominance structure of syrphids on *A. craccivora* Koch on cowpea during kharif 1997

Month/week		Mean number of syrphid larvae* per ten plants						Number of species recorded	Number of larvae per plant	Number of aphids per plant	Predator: Prey ratio
		A	B	C	D	E	F				
August	I	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0	0.0	9.70	-
	II	0(0)	1(100.00)	0(0)	0(0)	0(0)	0(0)	1	0.1	10.90	1:109
	III	1(33.33)	2(66.66)	0(0)	0(0)	0(0)	0(0)	2	0.3	65.70	1:219
	IV	3(33.33)	2(22.22)	2(22.22)	2(22.22)	0(0)	0(0)	4	0.9	243.90	1:271
	V	1(9.09)	2(18.18)	3(27.27)	5(45.45)	0(0)	0(0)	4	1.1	333.30	1:303
September	I	3(14.28)	4(19.04)	4(19.04)	10(47.61)	0(0)	0(0)	4	2.1	476.70	1:227
	II	2(8 69)	3(13.04)	9(39.13)	9(39.13)	0(0)	0(0)	4	2.3	770.50	1:335
	III	2(8.69)	6(26.08)	11(47.82)	4(17.39)	0(0)	0(0)	4	2.3	954.50	1:415
	IV	1(3 22)	4(12.90)	14(45.16)	12(38.70)	0(0)	0(0)	4	3.1	933.10	1:301
October	I	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0	0.0	8.70	-
	II	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0	0.0	15.80	-
	III	0(0)	1(100)	0(0)	0(0)	0(0)	0(0)	2	0.1	11.00	1:110
	IV	1(11.11)	2(22.22)	4(44.44)	2(22.22)	0(0)	0(0)	4	0.9	252.90	1:281
November	I	2(10.00)	5(25.00)	6(30.00)	7(35.00)	0(0)	0(0)	4	2.0	224.00	1:112
	II	4(12.90)	6(19 35)	12(38.70)	9(29.03)	0(0)	0(0)	4	3.1	551.80	1:178
	III	1(4.54)	8(36.36)	9(40.90)	4(18.18)	0(0)	0(0)	4	2.2	222.20	1:101
	IV	0(0)	3(37.50)	2(25.00)	3(37.50)	0(0)	0(0)	3	0.8	78.40	1:98

Figures in parentheses indicate percent population composition of syrphids A-*P. yerburiensis*, B-*P. serratus*, C-*I. scutellaris*, D-*D. aegrota*, E-*B. fletcheri* F-*B. linga*

observed from third week of April to second week of May and second week of September to fourth week of September in summer and kharif, respectively. Species complex and dominance structure of syrphid species were almost the same as in summer of previous year. However, during rainy season, *D. aegrota* appeared in the fourth week of August and it hold first position till the second week of September while in the previous year, it appeared only in the second week of September. *P. serratus*, *P. yerburiensis* and *I. scutellaris* remained active almost throughout both the seasons of both the years and *I. scutellaris* maintained a relatively higher population density, ranging from 1 to 51 and 2 to 14 larvae per ten plants with peak in the second week of May and 4th week of September when it constituted 78.46 and 45.16 percent of syrphid population in summer and kharif season, respectively. But as regards the dominance structure, its share in the community reached highest level, that is 84.61 and 47.82 percent at the end of May and third week of September, respectively. Except *B. fletcheri*, all syrphid species were observed in the second year and their order of appearance also was almost the same as in the first year (1996). In second year also, as regards to the dominance structure during whole season, *I. scutellaris* dominated both in summer (52%) and kharif (36%) followed by *P. yerburiensis* (29%) and *D. aegrota* (31%) during summer and kharif, respectively (Fig. 3).

The correlation of the aphid population with population of different syrphid species is depicted in Fig. 1 and 2. The total syrphid population and population of *I. scutellaris* exhibited highly significant positive correlation ($P = 0.001$) with aphid population during summer of both the study years (1996 and 97). During summer of 1997, *P. yerburiensis* and *P. serratus* also showed increasing trends with increasing aphid population.

During kharif season of 1996, *I. scutellaris*, *B. fletcheri*, *D. aegrota* and total syrphid populations were positively correlated with total aphid population, whereas, aphid population during kharif of 1997, exhibited positive correlation with *P. yerburiensis*, *P. serratus*, *I. scutellaris*, *D. aegrota* and the total syrphid population. These studies indicated that the syrphid showed a density dependent relationship with its host. The higher degree density dependent fluctuation exhibited by total syrphid predator population during August–October ($r = 0.859$ and $r = 0.845$ in 1996 and 1997, respectively) than during March–May ($r = 0.748$ and $r = 0.761$) indicated that it followed host population rapidly during kharif than in summer. Higher activity of coccinellid predators during August–October have been observed earlier by Srikanth and Lakkundi (1990) in cowpea ecosystem.

In general, the cowpea aphid and syrphid populations remained lower during 1997 as compared to 1996 probably due to heavy rains received during the month of October. However, the crop continued till November with aphid population also occurring till this period. In the first year, however, syrphid predators were able to keep the aphid population under reasonable check initially to some extent, but failed to do so later in the season, despite better larval counts. In both the years, high activity of syrphids coincided with peak aphid population but, predators generally failed to reach a ratio of 1 : 100 which is considered ideal for syrphids in controlling *Brevicoryne*

Summary, 1996

Summary, 1997

Kharif, 1996

Kharif, 1997
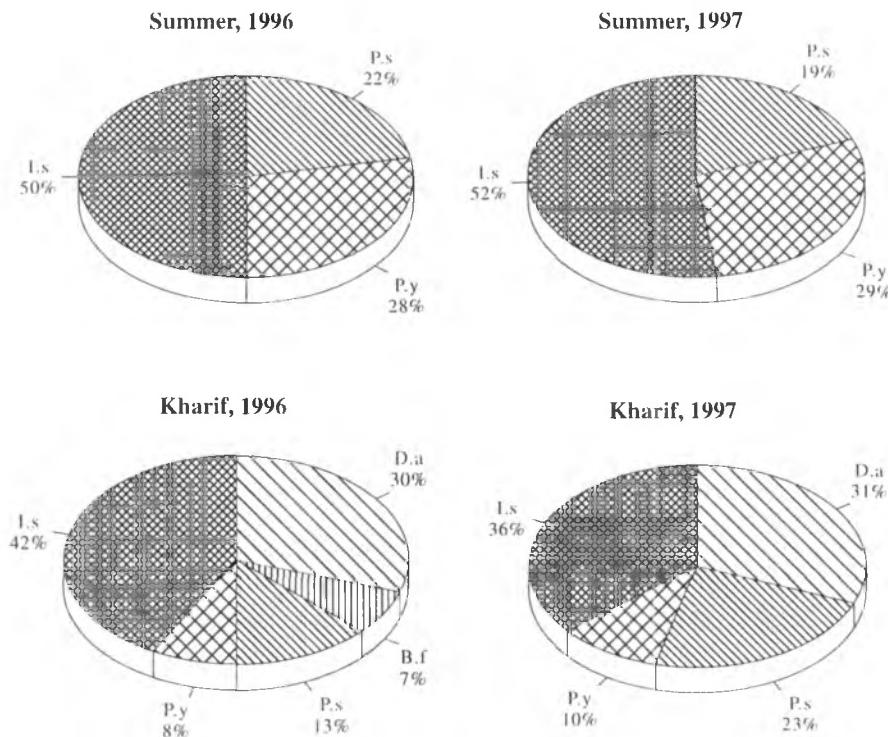
FIGURE 3. Dominance structure of different syrphid species during 1996 and 1997 P.y: *Paragus verburiensis*, P.s: *Paragus serratus*. B.f: *Betasyraphus fletcheri*, D.a: *Dideopsis aegrota*, I.s.: *Ischiodon scutellaris*.

brassicae Linnaeus and *Aphis pomi* De G. (Starka, 1976; Wunk, 1977). It is thus clear that predatory syrphids alone failed to afford control of cowpea aphid population in its rising phase. However, on account of their feeding and reproductive potential, syrphids can be used in biological control programme against *A. craccivora* in cowpea ecosystem by way of augmentation.

ACKNOWLEDGEMENTS

REFERENCES

Agarwala, B. K., Laska, P. and Raychaudhuri, D. V. (1984) Prey records of aphidophagous

syrphid flies from India (Diptera: Syrphidae), *Acta Ent. Bohemoslove.* **81**: 15–21.

Bernado, E. N. (1969) Effect of six host plants on the biology of black bean aphid, *Aphis craccivora* Koch, *Philippine Entomologist* **1**: 287–292.

Bock, K. R. and Conti, M. (1974) Cowpea aphid borne mosaic virus C. M. I./A. A. B. Descriptions of Plant viruses No. 140, Commonwealth Agricultural Bur: Farnham Royal, England.

Dhingra, S. (1993) Development of resistance in the bean aphid, *Aphis craccivora* Koch, to various synthetic pyrethroids with special reference to change in susceptibility of some important aphid species during the last one and a quarter decade, *J. Ent. Res.* **17**: 244–248.

Ghorpade, K. D. (1981) Insect prey of Syrphidae (Diptera) from India and neighbouring countries: A review and bibliography, *Tropical Pest Management* **27**: 62–82.

Kayumbo, H. Y. (1975) Cowpea pests in Tanzania, *Proc. IITA Collaborators Meeting on Grain Legumes Improvement. Int. Inst. Trop. Agric., Ibadan, Nigeria, June 9-13, 1975*, 179.

Saxena, H. P. (1978) Pests of grain legumes and their control in India, In: *Pests of Grain Legumes: Ecology and Control*, Singh, S. R., Taylor, T. A. and van Emden, H. F.: (Editors). Academic Press: London and New York, 15–23.

Singh, S. R. (1979) Resistance to pests of cowpea in Nigeria, In: *Pests of Grain Legumes: Ecology and Control*, Singh, S. R., Taylor, T. A. and van Emden, H. F.: (Editors). Academic Press: London and New York, 267–279.

Singh, S. R. and van Emden, H. F. (1979) Insect pests of grain legumes, *Ann. Rev. Entomol.* **24**: 255–278.

Singh, S. R. and Jackai, L. E. N. (1984) Insect pests of cowpea in Africa: Their lift cycle, economic importance and potential for control, In: *Cowpea Research, Production and Utilization*, Singh, S. R. and Richie, K. D.: (Editors). John Wiley: London, 217–223.

Srikanth, J. and Lakkundi, N. H. (1988) A method for estimating population of *Aphis craccivora* Koch on cowpea, *Tropical Pest Management* **34**: 335–337.

Srikanth, J. and Lakkundi, N. H. (1990) Seasonal population fluctuation of cowpea aphid *Aphis craccivora* Koch and its predatory coccinellids, *Insect Sci. Applic.* **11**: 21–26.

Starka, F. (1976) Biological control and economic effectiveness of aphidophagous enemies of the green cabbage aphid (*Brevicoryne brassicae* Linnaeus), *Rest Nauka* **4**: 82–91.

Wnuk, A. (1977) Evaluation of the effectiveness of *Episyrphus balteatus* (Deg.) (Diptera, Syrphidae) in the control of *Aphis pomi* Deg. (Homoptera, Aphididae), *Polskie Pismo Entomol.* **47**: 755–760.

Biochemical Changes in Spiralling Whitefly (*Aleurodicus dispersus* Russell) Infested Mulberry Leaf and their Influence on some Economic Parameters of Silkworm (*Bombyx mori* L.)

K. C. Narayanaswamy[*1], **T. Ramegowda**[2], **R. Raghuraman**[2] and **M. S. Manjunath**[2]

[1]*College of Sericulture, University of Agricultural Sciences, UAS, Chintamani, 563125, Kolar District, Karnataka, India*
[2]*Karnataka State Sericulture Research and Development Institute, Thalaghattapura, Kanakapura Road, 560062, Bangalore, India*

ABSTRACT: The studies conducted on the biochemical changes in the leaves of mulberry attacked by spiralling whitefly, *Aleurodicus dispersus* Russell (Homoptera: Aleyrodidae) revealed that the contents of moisture, chlorophyll 'a' and 'b', crude protein, sugars, nitrogen, phosphorus, calcium and magnesium were drastically reduced in infested leaves in comparison with the healthy leaves. In silkworms, it was found that the fifth instar larval duration was extended upto 8.50 days when reared on spiralling whitefly affected mulberry leaves. Considerable reduction in the fifth instar larval weight, cocoon weight, shell weight, cocoon-shell ratio and filament length was also observed when reared on affected leaves. It is therefore, evident that the feeding of spiralling whitefly affected leaves has adverse impact on the silkworm rearing performance. © 1999 Association for Advancement of Entomology

KEYWORDS: *Aleurodicus dispersus*, mulberry, biochemical analysis, *Bombyx mori*, rearing.

INTRODUCTION

The spiralling whitefly, *Aleurodicus dispersus* Russell (Homoptera: Aleyrodidae) originated from Central America got recently introduced into India (David and Regu, 1995), is a polyphagous pest infesting lower surface of leaves. This pest was first recorded on cassava at Trivandrum (Palaniswami *et al.*, 1995) and on 24 hosts including guava, mulberry, papaya, coconut, cashew and banana from Calicut in Kerala upto Kanyakumari in Tamil Nadu (David and Regu, 1995). Prathapan (1996) reported the outbreak and widespread of spiralling whitefly on 72 host plants in Kerala during summer. The occurrence of this pest on 9 species of crop plants, 8 species of ornamental plants, 3 tree species, and 2 species of weed plants has also been reported

*Corresponding Author
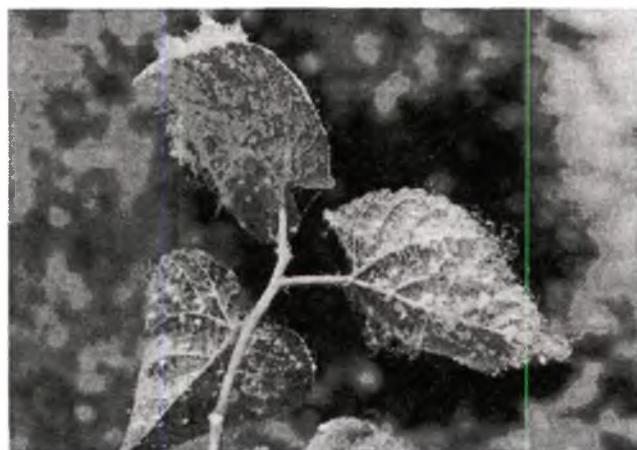
FIGURE 1. Mulberry plant covered with white mealy matter due to the attack of *A. dispersus*

from Kerala (Ranjith *et al.*, 1996). A severe infestation on guava was observed in Karnataka around 1995 (Mani and Krishnamoorthy, 1996) and by year 1998 this affected more than 100 plant species (Anonymous, 1998).

The occurrence of whitefly on mulberry causing serious damage has been reported from Coimbatore, Tamil Nadu (Douressamy *et al.*, 1997) and Bangalore, Karnataka (Geethabai *et al.*, 1998). The nymphs and adults of spiralling whitefly suck the sap from the mulberry leaves and cause yellowish speckling on the leaves. In the case of severe infestation the leaves crinckle, drop prematurely and sooty mould often appears and are unfit for feeding silkworms (Douressamy *et al.*, 1997). The biochemical changes in the spiralling whitefly affected mulberry leaf and their relevance on silkworms has been studied in the present study.

MATERIALS AND METHODS

The study was conducted between May and August, 1998 at KSSR & DI, Bangalore. Both spiralling whitefly affected (100% infested) and healthy (control) mulberry leaves of M_5 variety were collected and oven dried at 60° C to estimate the moisture content. The contents of chlorophyll 'a' & 'b', crude protein and sugars were estimated as per the modified procedure suggested by Bongale and Chaluvachari (1993). The levels of nitrogen, phosphorus, potassium, calcium, magnesium and sulphur were estimated adopting Jackson (1973) method. Three replications were maintained for all the parameters.

PM $\times$ NB$_4$D$_2$, the popular multi-bivoltine silkworm hybrid, was used for the present study and reared as cellular beds following the improved method of rearing (Krishnaswami, 1978). Three replications of 500 worms each for feeding experiments were maintained. Mulberry leaves from both infested (100% infested) and healthy

TABLE 1. Biochemical composition of spiralling whitefly affected and healthy leaves of mulberry (Variety - M$_5$)

Biochemical parameter	Spiralling whitefly affected leaf	Healthy leaf	Per cent change over healthy leaf
Moisture (%)	62.25 ± 2.11	70.21 ± 4.16	−11.34
Chlorophyll - a (mg/g)	1.98 ± 0.07	2.38 ± 0.04	−16.81
Chlorophyll - b (mg/g)	1.66 ± 0.11	2.14 ± 0.14	−22.43
Total Chlorophyll (mg/g)	3.64 ± 0.34	4.52 ± 0.42	−19.47
Crude protein (%)	20.22 ± 1.07	25.64 ± 1.67	−21.11
Sugars (%)	10.18 ± 0.99	12.12 ± 1.02	−16.01
Nitrogen (%)	2.06 ± 1.01	3.18 ± 0.98	−35.22
Phosphorus (%)	0.36 ± 0.01	0.49 ± 0.06	−26.53
Potassium (%)	1.23 ± 0.12	1.03 ± 0.13	+19.41
Calcium (%)	2.07 ± 0.16	3.20 ± 0.64	−35.31
Magnesium (%)	1.36 ± 0.34	1.78 ± 0.11	−23.59
Sulphur (%)	0.10 ± 0.02	0.09 ± 0.01	+11.11

garden were harvested and offered to treatment and control batches. The comparative evaluation of economic parameters were made with regard to fifth instar larval weight (from 1st day till spinning), fifth instar larval duration, cocoon weight, shell weight, cocoon shell ratio and filament length. These studies were restricted to the maximum feeding stage namely the fifth instar.

RESULTS AND DISCUSSION

Biochemical parameters

The moisture content in the spiralling whitefly affected leaves was less (62.25%) compared to healthy leaves (70.21%), exhibiting 11.34 per cent lower values over healthy leaves (Table 1). This reduction may be attributed to drawing of leaf sap by both nymphs and adults of *A. dispersus*. However, the moisture content in tukra (*Maconellicoccus hirsutus* Green) affected mulberry leaves (70.32 to 76.69%) was found to be significantly more compared to healthy leaves (66.97 to 70.58%). The increase in moisture content in tukra affected leaves is due to stunted growth (Veeranna, 1997). Though the moisture level is low in the whitefly infested leaves the vertical growth was not affected.

The levels of chlorophyll 'a' & 'b' and the total chlorophyll were strikingly reduced in the affected leaves compared to healthy leaves (Table 1). Das *et al.* (1994) reported significant reduction in total chlorophyll content in thrips (*Pseudodendrothrips mori* Nawa) infested leaves (2.024 mg/g) compared to healthy leaves (2.084 mg/g), which are comparable to present observations. The decreasing chlorophyll contents in spiralling whitefly infested leaves is attributed to the sap sucking nature of the pest, ultimately resulting in occurrence of yellowish speckling on the leaves (Douressamy *et al.*, 1997). However, the levels of total chlorophyll, chlorophyll 'a' and chlorophyll 'b'

TABLE 2. Effect of feeding of spiralling whitefly affected and
healthy leaves on larval weight of silkworm (PM × NB$_4$D$_2$)

Day (V instar)	Weight of 10 larvae (g)		Per cent change over healthy leaves
	Spiralling whitefly affected leaf	Healthy leaf	
1	7.83 ± 1.60	8.37 ± 1.99	−6.45
2	10.77 ± 2.63	12.47 ± 1.06	−13.63
3	12.57 ± 1.74	16.77 ± 1.77	−25.04
4	13.23 ± 1.46	17.77 ± 2.11	−25.54
5	15.17 ± 2.11	20.33 ± 1.69	−25.38
6	18.73 ± 1.89	25.33 ± 2.11	−26.06
7	19.21 ± 1.67	−	−
8	19.67 ± 2.11	−	−

strikingly increased in *M. hirsutus* infested mulberry leaves and the factor attributed for such increase was, failure of synthesis of chlorophyllase enzyme due to mealy bug attack (Babu *et al.*, 1994).

The levels of crude protein and sugars were reduced to the extent of 21.11 and 16.01 per cent respectively in spiralling whitefly affected leaves, compared to healthy leaves. Reduction in the levels of reducing sugars, total sugars and protein have also resulted due to infestation by *P. mori* (Anonymous, 1980; Sengupta *et al.*, 1990; Das *et al.*, 1994). Contrary to these findings, Veeranna (1997) reported higher levels of soluble carbohydrates and proteins in tukra affected mulberry leaves. Kumar *et al.* (1992) showed that the levels of proteins and carbohydrates of tukra and healthy leaves varied from variety to variety.

The levels of mineral constituents like nitrogen, phosphorus, calcium and magnesium were reduced to the extent of 35.22, 26.53, 35.31 and 23.59 per cent, respectively in spiralling whitefly affected leaves compared to control. However, the levels of potassium (1.23%) and sulphur (0.10%) were comparatively higher in affected leaves as compared to healthy leaves (N - 1.03%; S - 0.09%) (Table 1). The decrease in the levels of nitrogen, phosphorus, calcium and magnesium has also been observed in the case of leaves attacked by *P. mori* (Naik, 1997).

Effect of feeding spiralling whitefly affected mulberry leaves on the performance of silkworm

There was a 6.45, 13.63, 25.04, 25.54, 25.38 and 26.06 per cent reduction in fifth instar larval weight from first to sixth day of the instar, when fed with infested leaves over the healthy leaves (Table 2). It is seen that the larval weights reduced progressively as the age of the larvae advanced, indicating the progressive adverse effects on the worms. Here the worms were comparatively smaller in size, pale in colour, sluggish and showed reduced appetite over the worms which fed on healthy leaves. These factors may be the resultant of lower levels of moisture, proteins, sugars, chlorophyll and minerals (N, P, Ca, Mg) in affected leaves. The reduced appetite of worms when fed

TABLE 3. Effect of feeding of spiralling whitefly affected and healthy leaves
on certain economic parameters of silkworm (PM × NB₄D₂)

Parameter	Spiralling whitefly affected leaf	Healthy leaf	Per cent change over healthy leaf
V instar duration (days)	8.50 ± 0.99	6.29 ± 1.01	-35.13
Single cocoon weight (g)	1.06 ± 0.21	1.50 ± 0.20	-29.33
Single shell weight (g)	0.14 ± 0.004	0.24 ± 0.006	-41.32
Shell ratio (%)	13.39 ± 1.12	16.13 ± 0.98	-16.98
Filament length (m)	731.2 ± 8.26	880.3 ± 11.37	-16.94

on infested leaves may also be attributed to the presence white mealy matter (Figure 1) and the sooty mould associated with such leaves (Douressamy *et al.*, 1997). The feeding of tukra affected leaves (Kumar *et al.*, 1992) and thrips infested leaves (Naik, 1997) also resulted in significantly lowering larval weights in PCN and PM × NB₄D₂, respectively. On the contrary, significant increase in larval weight was recorded when worms fed on tukra affected leaves in the case of NB₄D₂ (Veeranna, 1997). The fifth instar duration of the worms fed on leaves attacked by spiralling whitefly occupied 8.50 days compared to 6.29 days in the case of worms reared on healthy leaves, thus expressing an extended growth duration when fed on infested leaves.

The cocoon weight, shell weight and the cocoon-shell ratio were 1.06 g, 0.14 g and 13.39 per cent respectively in the case of spiralling whitefly affected leaves as compared to 1.50 g, 0.24 g and 16.13 per cent, respectively in healthy leaves (Table 3). Such performance was observed when the silkworms were fed on tukra affected leaves in the case of PCN (Kumar *et al.*, 1992). The silk filament length was shorter (731.2 m) when the larvae were provided with spiralling whitefly affected leaves compared to longer filament length (880.3 m) as recorded for controls.

These results clearly indicate that the quality of the spiralling whitefly affected leaves is inferior as evidenced from the biochemical parameters. Further, the performance of the silkworms fed on infested leaves was poor, as reflected from the larval and cocoon parameters. It is obvious that the quality of mulberry leaves has predominating influence on the development of the worms and the quality of cocoons. This contention is supported by the literature on the influence of quality of mulberry leaves on the growth and development of silkworm (Ito and Arai, 1963; Radha *et al.*, 1978; Pillai and Jolly, 1985). It is, therefore, concluded that the feeding of spiralling whitefly affected leaves has the negative response on silkworms in respect of growth and cocoon economic parameters. The impact of this would be much greater if worms are fed on whitefly infested leaves from the beginning of larval stage till spinning.

REFERENCES

Anonymous, (1980) Studies on thrips infesting mulberry, *Ann. Rept.*, CSR & TI: Mysore, 128.
Anonymous, (1998) Whitefly menace to end as steps are afoot to import its predator. *Deccan Herald*, June, 7th.

Babu. R. S., Dorcus, D. and Vivekanandan, M. (1994) Changes in morphophysiology, water relations and nutrients in tukra diseased leaves of a few mulberry varieties, *J. Seric. Sci. Jpn.* **63(3)**: 183–188.

Bongale, U. D. and Chaluvachari, (1993) Evaluation of four mulberry varieties by leaf biochemical and bioassay with *Bombyx mori* L., *J. Indian Bot. Soc.* **72**: 59–62.

Das, C., Shivnath, and Rao, K. M. (1994) An investigation of morphophysiological changes due to thrips infesting mulberry, *Morus alba* L., *Geobios* **21(2)**: 109–113.

David, B. V. and Regu, K. (1995) *Aleurodicus dispersus* Russell (Aleyrodidae: Homoptera) a whitefly pest, new to India, *Pestology* **29(3)**: 5–7.

Douressamy, S., Chandramohan, N., Sivaprakasam, N., Subramanian, A. and SundaraBabu, P. C (1997) Management of spiralling whitefly, *Indian Silk* **36(6)**: 15–16.

Geethabai, M., Narayanaswamy, K. C., Marimadaiah, B. and Ramegowda, T. (1998) The spiralling whitefly, *Aleurodicus dispersus* Russell (Homoptera: Aleyrodidae), a pest of mulberry in Karnataka, *Indian J. Seric.* (Communicated).

Ito, T. and Arai, N. (1963) Food values of mulberry leaves for the silkworm, *Bombyx mori* L. determined by means of artificial diets. 1: Relationship between kinds of mulberry leaves and larval growth, *Bull. Seric. Expt. Stn.* **18(4)**: 226–229.

Jackson, M. L. (1973) *Soil Chemical Analysis*, Princtice Hall Pvt. Ltd.: New Delhi, India.

Krishnaswami, S. (1978) *New Technology of Silkworm Rearing*, CSR & TI: Mysore, India.

Kumar, P., Kishore, R., Noamani, M. K. R. and Sengupta, K. (1992) Effect of feeding tukra affected mulberry leaves on silkworm rearing performances, *Indian J. Seric.* **31(1)**: 27–29.

Mani, M. and Krishnamoorthy, A. (1996) Spiralling whitefly and its natural enemies on guava in Karnataka, *Insect Environment* **2(1)**: 12–13.

Naik, S. L. (1997) Bioecology of thrips infesting mulberry, M.Sc. (Seri.) Thesis, UAS, Bangalore, 77.

Palaniswami, M. S., Nair, R. R., Pillai, K. S. and Thankappan, M. (1995) Whiteflies on cassava and its role as vector of cassava mosaic disease in India, *J. Root Crops* **22(1)**: 1–8.

Pillai, S. V. and Jolly, M. S. (1985) An evaluation on the quality of mulberry varieties raised under hill conditions and the crop results of *Bombyx mori* (L.), *Indian J. Seric.* **24(2)**: 48–52.

Prathapan, K. D. (1996) Outbreak of Spiralling whitefly, *Aleurodicus dispersus* Russell (Aleyrodidae: Homoptera) in Kerala, *Insect Environment* **2(2)**: 36–38.

Radha, N. V., Lathchoumanane, S., Rajeswari, and Obliswami, G. (1978) Effect of feeding with the leaves of different mulberry varieties on the races of silkworm, *All India Symp. Seric. Sci.*, (Abstract). Bangalore, UAS, 52.

Ranjith, A. M., Rao, D. S. and Thomas, I. (1996) New host records of the whitefly, *Aleurodicus dispersus* Russell in Kerala, *Insect Environment* **2(2)**: 35–36.

Sengupta, K., Govindiah, Baig, M. and Kumar, P. (1990) *Handbook of Pest and Disease Control of Mulberry and Silkworm*, ESCAP: Bangkok, Thailand, 88.

Veeranna, G. (1997) Biochemical changes in tukra leaves of mulberry and its effect on economic characters of mulberry silkworm, *Bombyx mori* L, *Entomon* **22(2)**: 129–133.

Influence of Prey Species on Feeding Preference, post-embryonic Development and Reproduction of *Coccinella transversalis* F. (Coccinellidae: Coleoptera)

A. Babu

Entomology Research Institute, Loyola College, 600034, Chennai, India

ABSTRACT: Increased feeding preference and reproductive performance of the predatory ladybird beetle *Coccinella transversalis* were observed on the aphid prey *Aphis fabae* Scopoli, as against *Aphis nerii* Boyr. Chemical analysis of the different prey species in relation to total free amino acids, proteins, carbohydrates and lipids showed maximum values for *A. fabae*, indicating increased nutritional quality of this prey species. On the preferred prey species *A. fabae*, the age- specific fecundity, as well as the various life table parameters of the coccinellid predator were maximum.
© 1999 Association for Advancement of Entomology

KEYWORDS: Prey preference, prey nutritional quality, Predatory efficiency

INTRODUCTION

Interactions between insects and plants are strongly influenced by higher trophic levels, which include the predators and parasites. These natural enemies play a vital role in the regulation of pest populations and a large number of coccinellids are known to prey upon several species of economically important phytophagous insects which include aphids and coccids and are potentially useful biocontrol agents checking the population build-up of insect pests (Hodek, 1973). Apart from the influence of various abiotic factors, physical and chemical attributes of prey play a vital in altering the growth parameters of the predator, its reproductive potential and life table characteristics (Haque & Islam, 1982; Babu, 1991). Against this background, an attempt has been made to evaluate prey preference, development, and reproductive performance of *Coccinella transversalis* (a predator of a number of aphid species, scale insects in cultivated vegetable crops) on two different species of aphids namely, *Aphis fabae, and Aphis nerii* serving as prey. The aim of this study is to assess the effect of prey quality on the growth and reproductive performance of *C. transversalis* and to compute life-table data to be able to emphasise its predictive capabilities, so as to be of use in adopting integrated pest management strategies.

TABLE 1. Prey preference of *Coccinella transversalis* in (I) free-choice as well as (II) no choice situations

Experimental regime	Predatory feeding response #	Percentage preference	t-value
I. Free choice			
Aphis fabae	15.9 ± 0.5	79.5	
Aphis nerii	4.1 ± 0.5	20.5	33.937**
II. No choice			
Aphis fabae	19.4 ± 0.4	97	
Aphis nerii	12.4 ± 0.4	62	31.55**

values represent mean number of adults recorded on prey/h/replicate
Significant that 0.1%(**)

TABLE 2. Effect of prey type on the developmental duration, adult longevity fecundity, and survival % of *Coccinella transversalis*

Biological Parameters	Preytype		t-value
	Aphis fabae	*Aphis nerii*	
#Larval/Pupal duration (in days)	17.0 ± 2.0	22.6 ± 0.8	3.509*
#Longevity (in days)	40.8 ± 1.6	30.2 ± 0.4	12.480**
#Fecundity (eggs/female)	536 ± 8.1	376 ± 7.5	30.346**

#Values represent mean $\pm$ SD of five replicates
Significant at 0.05%(*), and 0.1%(**)

MATERIALS AND METHODS

Adults and larvae of the predatory coccinellid were collected from nearby vegetable fields and maintained for raising a stock culture, as described by Manjunath (1988), in the laboratory inside glass troughs (25×10 cm) at $25 \pm 2\,°C$, 14L : 10 D, and $65 \pm 5\%$ RH with their open tops covered with muslin cloth for ventilation. From this culture, neonate larvae and adults ($<$ 24 hrs old) were taken as and when needed, for utilization in the different experiments arranged to record various desired biological observations on the two different aphid species. The tests were conducted at the same temperature, photoperiod and relative humidity conditions as described for maintenance of stock culture.

Biochemical analysis

The study was restricted to gravimetric assessment of total a) free amino acids (Moore & Stein, 1948), b) proteins (Lowry *et al.*, 1951), c) carbohydrates (Dubois *et al.*, 1956), and lipids (Folch *et al.*, 1957) for each of the two selected prey species. One hundred mg of prey was taken for each biochemical estimation which was replicated five times.

TABLE 3. Biochemical profiles of two aphid species

Prey	Free amino acids (mg/g)	Proteins (mg/g)	Carbohydrates (mg/g)	Lipids (mg/g)
A. fabae	0.816 ± 0.06	173.8 ± 9.7	216.7 ± 7.9	9.2 ± 1.72
A. nerii	0.352 ± 0.01	112.4 ± 7.93	150.0 ± 7.52	9.2 ± 1.72

Values represent mean ± SD of five replicates

TABLE 4. Age specific life table parameters of *Coccinella transversalis* on three different aphid prey

Parameters	Prey species	
	Aphis fabae	Aphis nerii
Meanlength of generation time (Tc)	33.72	38.19
Innate Capacity for increase (rc)	0.08	0.06
Intrinsic rate of natural increase	0.08	0.06
Corrected (rm)	0.765	0.062
Corrected generation time (T)	31.62	35.5
Finite rate of increase in number (λ)	1.08	1.06

Prey preference

Investigation of prey preference entailed, utilisation of 20 newly emerged (< 24 hrs old) adults of mixed sexes. Feeding preference of the adult was ascertained by offering (1) free-choice situation wherein the two different prey species were simultaneously provided and (2) a no- choice situation in which only one of the prey species was given as food. Coccinellid adults were starved for 24 hrs before the commencement of these experiments. The prey adult number of either species of aphid was limited to 75 individuals held on their respective host leaves. In free choice tests, they were placed at an equal distance from the centre of a glass trough (25 × 10 cm) functioning as an experimental chamber. Twenty individuals of *C. transversalis* were introduced at the centre of this chamber and the number of coccinellids attracted towards each prey was recorded at hourly intervals for a period of 8 hrs. Similar observations were taken in no-choice tests as well. Each type of trial was repeated 5 times with fresh batches of coccinellids and prey insects and the percentage of preference at the two tested situations was calculated.

Post-embryonic developmental duration, longevity and life table studies

For determining post -embryonic developmental time of *C. transversalis* reared separately on *A. fabae* or *A. nerii*, 20 newborn larvae were utilised at the start of the experiment. The time taken for completion of each larval instar as well as the pupal stage and the number of adults that ultimately emerged were recorded. These adults were also provided the same prey on which they were reared in order to study adult longevity, and total egg output of the female during her life time. Data associated with

life table parameters of the predator raised on the two different prey species for two consecutive generations were also obtained. All trials relating to each aspect of study were repeated 5 times involving fresh individuals per test.

RESULTS

Feeding preference experiments revealed that *C. transversalis* adults showed a selective preference for *A. fabae*, in a free-choice situation and the difference was significant (Table 1). But, in a no-choice situation their feeding on *A. nerii* was compelled by starvation.

Duration of post-embryonic development of the predator reared on the two different prey species ranged from 17–22 days (Table 2). However, young ones reared on *A. fabae* emerged into adults quicker than their counterparts raised on *A. nerii*. The adult longevity ranged from 30–40 days on the different prey species. The total egg out put was also high when individuals were fed on *A. fabae* (Figs. 1–3).

Biochemical estimations of the different prey species in respect of total free amino acids, protein, carbohydrates and lipids revealed that all these primary nutrients were relatively higher in *A. fabae* than in *A. nerii* (Table 3).

Data on the life table analysis of the predator indicated that the net reproductive rate of *C. tranversalis* was maximum on *A. fabae* (Table 4). The duration of development from egg to adult, when fed on two different aphid species showed shorter generation time, higher intrinsic rate of population increase, and increased age specific fecundity (mx) on *A. fabae* Correspondingly, the population doubling time decreased from 11.17 days on *A. nerii* to 9.12 days on *A. fabae*.

DISCUSSION

The host seeking behaviour and host/prey selection form important criteria while considering coccinellids as spontaneous biological control agents of aphids and scale insects (Ives, 1981; Richards, 1981; Shah, 1982; Babu, 1991). In other words, the predatory potential and prey exploitation of the coccinellids have been closely linked with the suitability of prey species (Rawat & Modi, 1969) and successful prolongation of niche utilisation as was in the case of the aphid predator *C. transversalis*.

Food quality in terms of its nutritional value also has significant impact on the reproductive performance of coccinellid (Hamalailnen & Markkula, 1972). In the present investigation, the importance of the ratio and the levels of primary metabolites of the prey species as crucial factors have been highlighted with reference to the predatory coccinellid *C. transversalis*. The observations revealed the ready acceptance of this coccinellid only on such prey with high contents of free amino acids, proteins, carbohydrates and lipids. The predatory efficiency or the active uptake of food was far greater in the adults (especially in females) compared to the early larval stages. However, the III and IV instar larvae were found to be more voracious than adult males.

The vital link between nutrition and continued survival of a species in a habitat
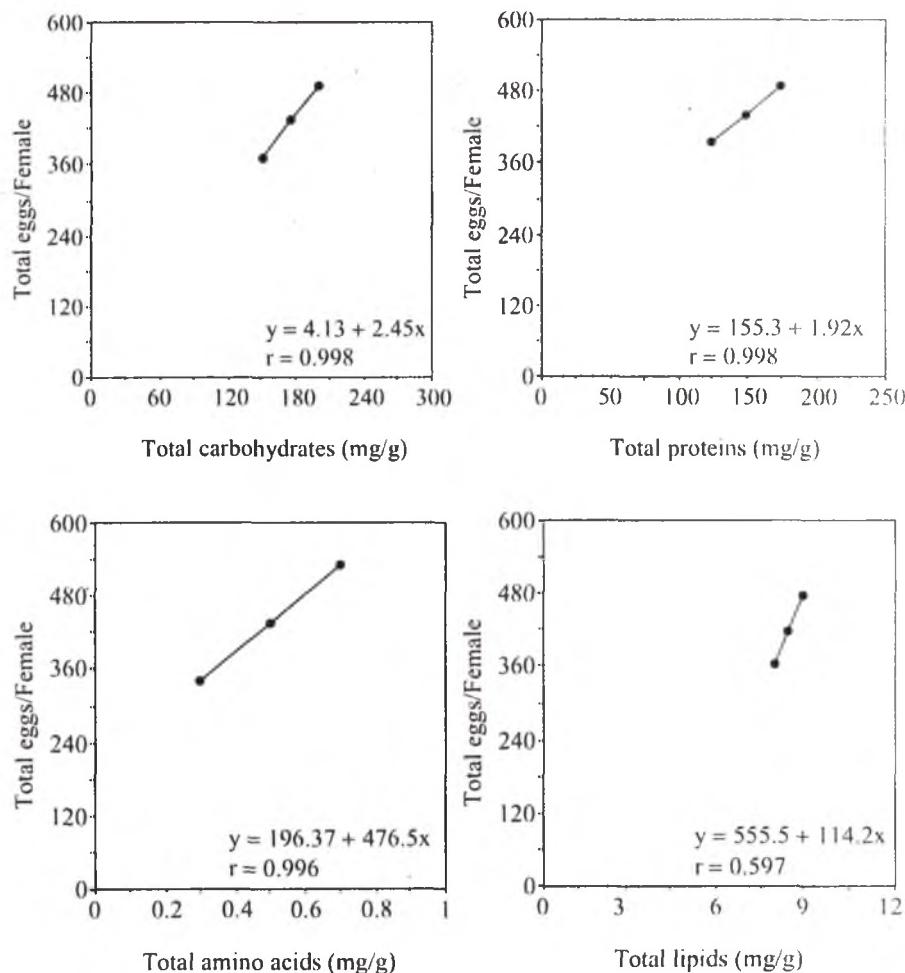
FIGURE 1. Regression line showing the correlation coefficient between the levels of primary metabolites and fecundity of *Coccinella transversalis* when fed on different aphid species.

is its reproductive capacity that contribute to the sustenance of a population. The energy derived on feeding is diverted towards various metabolic functions, important among which is reproduction. High quality nutrition enabled greater number of progeny (Hamalailnen & Markkula, 1972) as exemplified by *Macrosiphum rosae* being significantly more useful as an energy resource compared to *Myzus persicae*. Observations on *C. transversalis* pertaining to faster rate of development (17 days) and increased total egg yield (536 eggs) when fed on the preferred prey species *A. fabae* are in agreement with the earlier findings on different species of predatory coccinellids as reported by Saharia (1980); Campbell *et al.* (1980); Haque & Islam
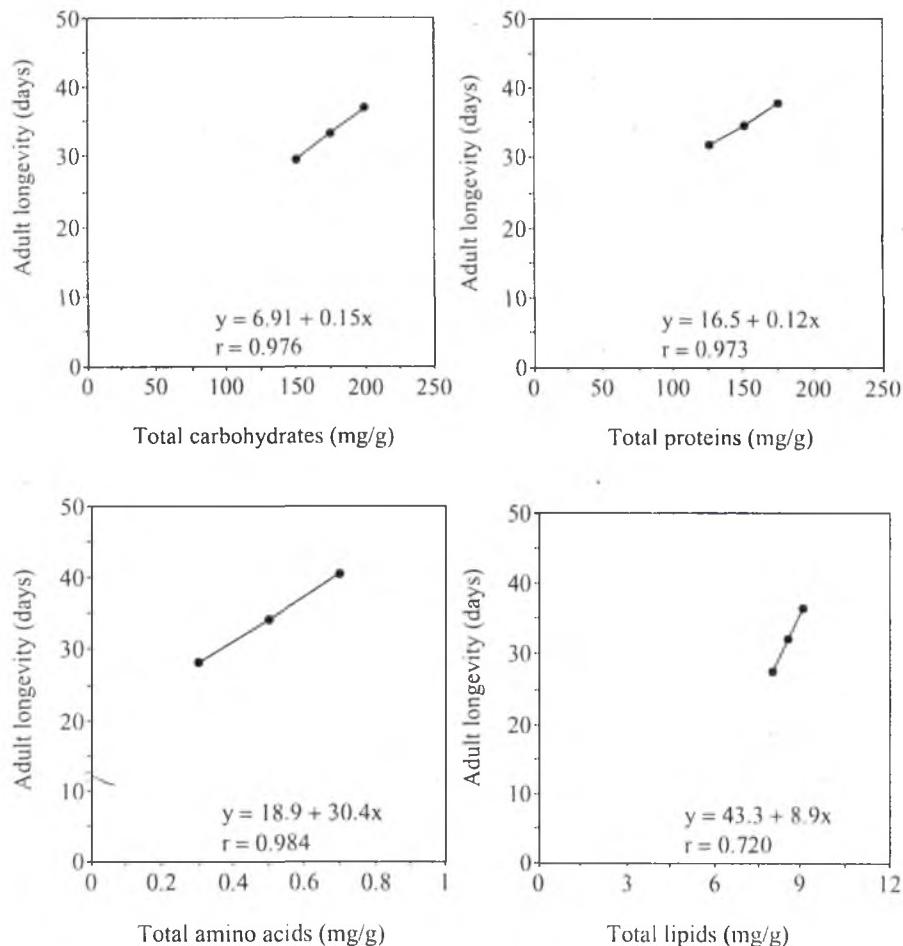
FIGURE 2. Regression line showing the correlation coefficient between the levels of primary metabolites and adult longevity of *Coccinella transversalis* when fed on different aphid species.

(1982), and Goutam (1989). Our results also confirm the observations of Hamalailnen & Markkula (1972) who reported the fecundity of *C. septempunctata* to be 964 and 411 eggs when the prey was *Macrosiphum rosae* and *Myzus persicae* respectively, indicating the fact that high quality nutrition enables production of greater number of progeny in predatory coccinellids.

In conclusion, it can be stated that the performance of *C. transversalis* as a potential biological control agent is reflected by the effect of its prey quality on the predators feeding response, overall development, reproduction and life table characteristics.
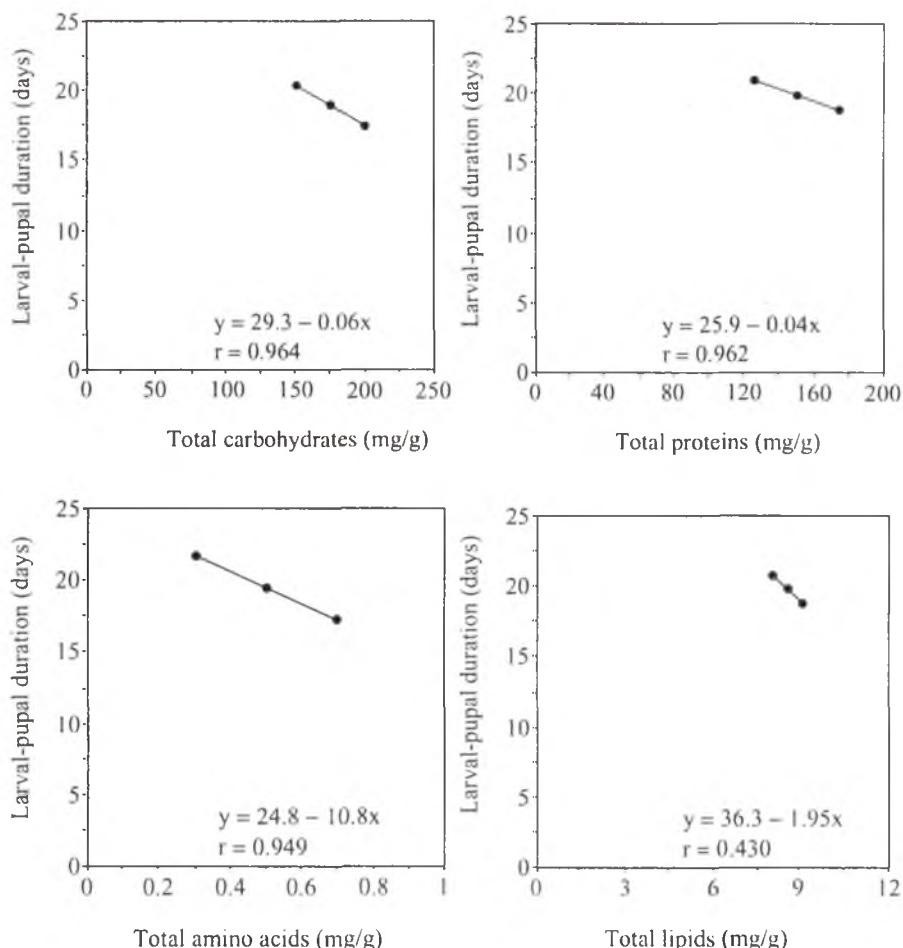
FIGURE 3. Regression line showing the correlation coefficient between the levels of primary metabolites and larval-pupal duration of *Coccinella transversalis* when fed on different aphid species.

REFERENCES

Agarwala, B. K. and Choudhuri, M. S. (1995) Use of alternate food in rearing of aphidophagous ladybird beetle, *Menochilus sexmaculatus* Fabr., *Entomon* 20(2): 19–23.

Babu, A. (1991) Bioecological studies on some phytophagous and predatory coccinellids (Insecta : Coleoptera : Coccinellidae), Ph.D. Thesis, University of Madras.

Babu, A. (1993) Predatory efficiency, reproductive potential and bioenergetics of *Coccinella transversalis* F. and *Menochilus sexmaculatus* F. (Colleoptera : Coccinellidae) in relation to aphid (Homoptera : Aphididae) prey quality, *Phytophaga* 5: 121–133.

Birch, S. (1948) The intrinsic rate of natural increase in an insect population, *J. Anim. Ecol.* 17: 15–26.

Bhat, P. K., Chacko, M. J. and Sreedharan, K. (1981) Biology of the ladybird beetle *Cryptolae-mus montrouzeri* Mulsant, a predator of mealy bugs, *Proc. Second. Ann. Symp. Plantation crops*, 221–226.

Campbell, R. K., Farris, T. N., Perring, T. J., Leonard, M. E., Cartwright, B. O. and Eikenbary, E. (1980) Biological observation of *Menochilus sexmaculatus* reared on *Schizaphis graminum*. *Ann. Ent. Soc. Am* (7): 153–157.

Dubois, M., Gilles, K. A., Hamilton, J. K., Reber, P. A. and Smith, F. (1956) Colorimetric determination of sugars and related substances, *Analytical Chemistry* 28: 351–356.

Fisher, T. W. (1963) Mass culture of *Cryptolaemus and Leptomastix*- natural enemies of citrus mealy bug, *Calif. Agric. Exp. sta. Bull.* 797: 39.

Folch, J., Less, M. and Sloane-Stanley, G. H. (1957) A simple method for isolation and purification of total lipids from animal tissues, *J. Biol. Chem.* 226: 497–506.

Goutam, R. D. (1989) Influence of different host on the adults of *Menochilus sexmaculatus* (Fabr). (Coleoptera : Coccinellidae), *J. Biol. Control.* 3(2): 90–92.

Hamalailnen, M. and Markkula, M. (1972) Effect of type of food on fecundity in *Coccinella septumpunctata* L. (Coleoptera : Coccinellidae), *Ann. Ent. Fenn.* 38(4): 195–199.

Hodek, I. (1973) *Biology of Coccinellidae*, Dr. W. J. Junk Publishers: The Hague, (Holland), 259.

Howe, R. N. (1953) The rapid determination of intrinsic rate of increase of an insect population, *Ann. Appl. Biol.* 40: 134–155.

Haque, M. E. and Islam, M. A. (1982) Effect of 3 species of aphids as food on the fecundity of ladybird beetle, *Bangaladesh J. Agric.* 3: 373–376.

Ives, P. M. (1981) Feeding and egg production of two species of coccinellids in laboratory, *Canadian Entomologist* 113: 999–1005.

Lowry, R. K., Rosebrough, W. J., Farr, A. L. and Randall, R. J. (1951) Protein measurements with folin phenol reagents, *J. Biol. Chem.* 193: 263–275.

Manjunath, M. (1988) Practical Aspects to Mass production, Packing and release of Coccinellid predators Chapter 9 pp 266–271 and Production and utilisation of coccinellid predators Chapter 16 pp 1258–1266, In: *Biocontrol Technology for Sugarcane Pest Management*, David, H. and Eswaramurthy, S.: (Editors). Sugarcane Breeding Institute: Coimbatore, 378.

Liotta, G. and Mieno, G. (1963) Mass culture of *Cryptolaemus and Leptomastix*- natural enemies of citrus mealy bug, *Calif. Agric. Exp. Sta. Bull.* 797: 39.

Mani, M. and Thantordarya, T. S. (1987) Development and feeding potential of predator *Cryptolaemus montrouzeri* Muls. on the grape mealy bug, *Maconellicoccus hirsutus* (Green), *J. Biol. Control* 1(1): 19–22.

Moore, S. and Stein, W. H. (1948) Photometric ninhydrin methods for use in chromatography of amino acids, *J. Biol. Chem.* 176: 367–388.

Rawat, R. R. and Modi, B. N. (1969) Studies on *Nephus regularis* (Coleoptera : Coccinellidae) a predator of striped mealybug in Madhya Pradesh (India), *Ann. Ent. Soc. Amer.* 62: 953–956.

Richards, A. M. (1981) *Rhyzobius ventralis* (Erichson) and *Rhyzobius forestieri* (Mulsant), (Coleoptera: Coccinellidae): their biology and value in the control of scale insects, *Bull. Ent. Res.* 71: 33–46.

Saharia, D. (1980) Some aspects of biology of coccinelli predators associated with *Aphis craccivora* Koch. on cowpea, *J. Res. Assam. Agric. Univ.* 1: 82–89.

Shah, M. A. (1982) The influence of plant surfaces on the searching behaviour of coccinellid larvae, *Ent. Exp. Appl.* 31: 377–380.

Cocoon and Shell Weight Inheritance in a Ten Parent Diallel Cross in the Mulberry Silkworm, *Bombyx mori* L.

M. Tajimul Haque*, Ismat Ara Ali, Sowdagar Mahfuzar Rahman and M. Abdus Salam

Bangladesh Sericulture Research & Training Institute, Rajshahi-6100 (M. T. Haque) and Department of Zoology, Rajshahi University, Rajshahi 6205,,

ABSTRACT: Inheritance of cocoon and shell weight in the mulberry silkworm, *Bombyx mori* L. were studied in a ten-parent complete diallel experiment. The graphical analysis and component of variation and rations depicted the actual importance of additivity and dominance where the contribution of the latter was greater compared to additive effect. However the presence of an overall over dominance in cocoon weight to an average partial dominance in shell weight was observed which reasonably was unidirectional in nature indicating the harmonious distribution of positive and negative alleles. For both cocoon and shell weight the varieties Nistid white, O_5 and R_1S_1 possessed an excess of dominant genes of positive nature. The narrow and broad sense heritability were 24.73 and 59.19 in cocoon weight while 55.20% and 98.64% in shell weight were estimated. © 1999 Association for Advancement of Entomology

KEYWORDS: *Bombyx mori* L. diallel cross, cocoon and shell weight

INTRODUCTION

The improvement of silkworm varieties *Bombyx mori* L. are of great importance to increase quality silk production in any newly emerging silk producing country in the world. The inherent quality of a variety can be improved by genetic manipulation or breeding of a population. Therefore, to initiate any effective and meaningful breeding programmes, sound knowledge on the nature and number of genes controlling the expression of a quantitative trait is of paramount importance to the breeder. Gene action and interaction had been studied by the application of different sophisticated biometrical methods of which diallel analysis is a quick method through which the information on the genetic architecture can be obtained as early as in F_1 generation (Jinks & Hayman, 1953; Allard, 1956; Jinks, 1956). In mulberry and non mulberry silkworm, this diallel technique has been successfully used by many workers (Krishnaswamy *et al.*, 1964; Jolly *et al.*, 1969; Gamo *et al.*, 1985; Sarkar *et al.*, 1991). Very recently and for the first time, a six parent diallel analysis with multivoltine

*Corresponding author

TABLE 1. Analysis of variance of $(Wr - Vr)$ and $(Wr \pm Vr)$ values of the ten parent diallel for cocoon weight

Item	df	MS	P
$Wr - Vr$ array differences	9	0.000027	NS
$Wr - Vr$ Error	18	0.000077	
$Wr \pm Vr$ array differences	9	0.000005479	NS
$Wr \pm Vr$ Error	18	0.0000107	

silkworm race, *Bombyx mori* L. was tried by Rahman (1994) in Bangladesh. The present study has been made to find out the nature of gene action involved in the expression of cocoon and shell weight in a ten-parent diallel analysis of silkworm.

MATERIAL AND METHODS

Ten silkworm races namely Nistari (M) NSRI(O), Nistid white, BSR-1(W), O₅, BSR-3(M), MBW-O62(D), BSRI-83/3, Pure Mysore and R_1S_1 were employed for this diallel study. Crosses were made in diallel fashion among the varieties in all possible combinations with reciprocal producing 90 F_1 hybrids constituted the materials of this experiment. The eggs of all the genotypes were brushed on rearing tray (90 cm × 75 cm) and larvae were counted after 2nd moult and reared upto final stage under ideal condition (Temp. $26 \pm 2\,^\circ$c and humidity $80 \pm 5\%$). A randomized block design with three replications and 400 larvae for each replication were maintained. After cocoon harvest data collected on cocoon and shell weight were used to construct diallel table and analysis were made following the diallel technique of Hayman (1954); Jinks (1954) and Johnson & Aksel (1959).

RESULTS

Analysis of variance of $(Wr - Vr)$ and $(Wr \pm Vr)$ values, components of variation and their ratios obtained from ten parent diallel for cocoon weight and shell weight are presented in Tables 1–3 while the Wr, Vr and standarized deviation graphs are shown in Fig. 1–4.

The Wr, Vr graph along with regression line drawn for cocoon and shell weight could be seen in Fig. 1 & 2. The regression coefficient in both the cases ($b = 0.074 \pm 0.164$ & $b = 0.00013 \pm 0.00002$) were significant but did not deviate significantly from the unit slope indicating the probable absence of non-allelic interaction in this diallel experiment. Analysis of variance of $Wr - Vr$ (Tables 1 & 2) indicated an insignificant $Wr - Vr$ item which was also an indication of absence of nonallelic interaction. The $Wr + Vr$ analysis of variance for both cocoon and shell weight failed to detect any dominant recessive relationship among the parents (Tables 1 and 2).

The regression line for cocoon weight cutting the Wr axis below the point of origin suggesting an over dominance overall loci (Fig. 1). But incase of shell weight
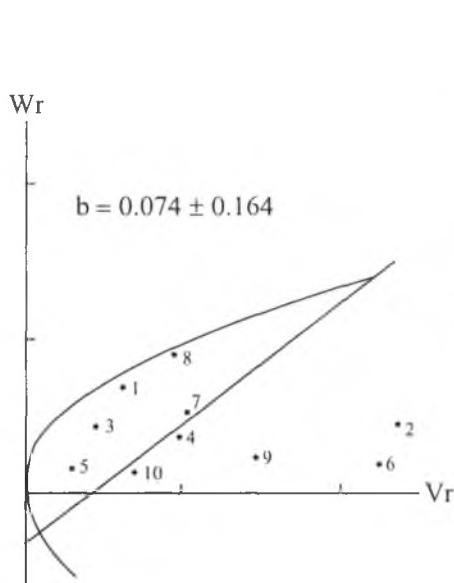
Fig. 1
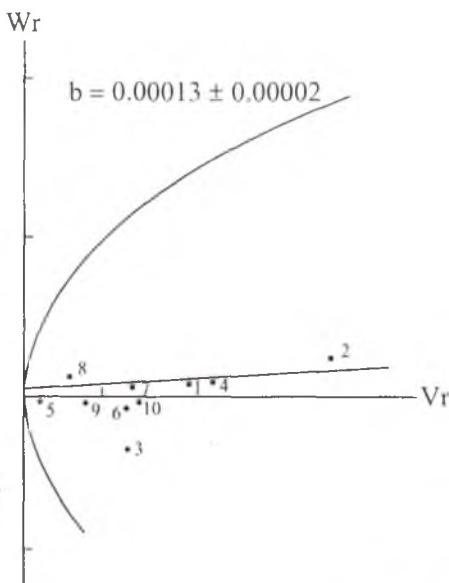
Fig. 2

FIGURE 1. The Wr/Vr graph for cocoon weight.
1. Nistari (M); 2. NSRI (O); 3. Nistld (W); 4. BSR-1 (W); 5. O_5; 6. BSR-3 (M); 7. MBW-062 (D); 8. BSRI-83/3; 9. Pure Mysore 10. $R_1 S_1$.

FIGURE 2. The Wr/Vr graph for shell weight.
1. Nistari (M); 2. NSRI (O); 3. Nistld (W); 4. BSR-1 (W); 5. O_5; 6. BSR-3 (M); 7. MBW-062 (D); 8. BSRI-83/3; 9. Pure Mysore 10. $R_1 S_1$.

TABLE 2. Analysis of variance of $(Wr - Vr)$ and $(Wr \pm Vr)$ values of the ten parent diallel for shell weight

Item	df	MS	P
$Wr - Vr$ array differences	9	0.00000001	NS
$Wr - Vr$ Error	18	0.000000006	
$Wr \pm Vr$ array differences	9	0.000000014	NS
$Wr \pm Vr$ Error	18	0.000000008	

the Wr, Vr graph (Fig. 2) showed that the regression line cuts the Wr axis above the point of origin suggesting an average partial dominance. The recurrent parents of array 2 (NSRI-O) was far away from the point of origin possessing an excess of recessive genes which was responsible for poor shell weight in the silkworm. But the arrays 5, 8 and 9 (O_5, BSRI-83/3 and Pure Mysore) were located near the point of origin of the regression line which bore excess of dominant genes. Similarly the array
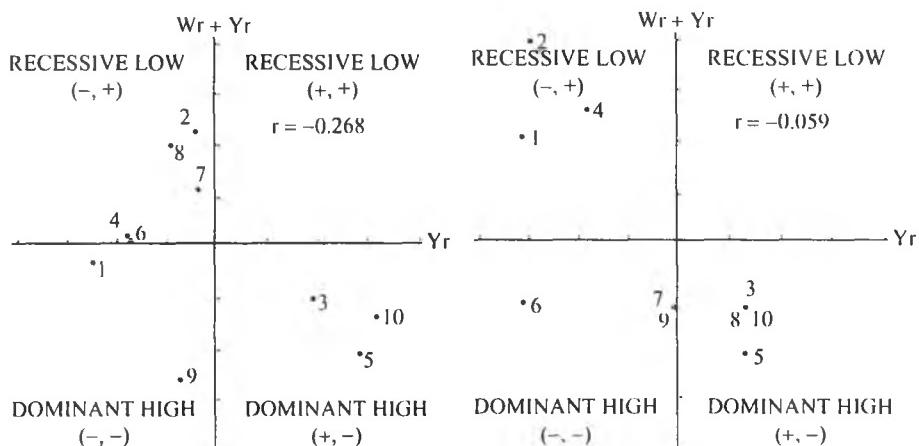
Fig. 3   Fig. 4

FIGURE 3. The standardized deviation graph for cocoon weight in *B. mori.*
1. Nistari (M); 2. NSRI (O); 3. Nistld (W); 4. BSR-1 (W); 5. O_5; 6. BSR-3 (M); 7. MBW-062 (D); 8. BSRI-83/3; 9. Pure Mysore 10. R_1 S_1.

FIGURE 4. The standardized deviation graph for shell weight in *B. mori.*
1. Nistari (M); 2. NSRI (O); 3. Nistld (W); 4. BSR-1 (W); 5. O_5; 6. BSR-3 (M); 7. MBW-062 (D); 8. BSRI-83/3; 9. Pure Mysore 10. R_1 S_1.

TABLE 3. Component of variation and their ratios obtained from ten parent diallel analysis

Components & ratios	Estimated values with standard error	
	Cocoon weight	Shell weight
$\hat{E}$	0.0013 ± 0.00033	0.000013 ± 0.00015
$\hat{D}$	0.00068 ± 0.000109	0.000174 ± 0.000011
$\hat{F}$	0.00176 ± 0.00252	0.000325 ± 0.00013
$\hat{H}_1$	0.00349 ± 0.000233	0.001770 ± 0.0014
$\hat{H}_2$	0.00437 ± 0.000198	0.001516 ± 0.000010
$\hat{h}^2/\hat{H}_2$	0.448	0.46356
$\sqrt{(\hat{H}_1/\hat{D})}$	2.267	0.98957
$1/4(\hat{D}/\hat{H}_1)$	0.0007	0.00159
$\hat{H}_2/4\hat{H}_1$	0.31236	0.21422
$1/2\hat{F}/\sqrt{\hat{D}}/(\hat{H}_1 - \hat{H}_2)$	0.17925	0.77239
Heritability (Narrow sense)	0.24733	0.55206
Heritability (Broad sense)	0.59194	0.9864

points 1, 3, 4, 6, 7 and 10 (Nistari (M), Nistid (W), BSR-1 (W), BSR-3 (M), MBW-062 (D) and $R_1 S_1$) occupying the intermediate positions along the regression line possessed more or less equal proportion of dominant and recessive genes (Fig. 2). For cocoon weight the distribution of array points in the graph showed that the parents had separated into two distinct group along the regression line. The first group possessed most of the dominant genes in their recurrent parents array 1, 3, 4, 5, 7, 8, and 10 (Nistari (M), Nistid (W), BSR-1 (W), O_5, MBW-062 (D), BSRI-83/3, and $R_1 S_1$) where as the arrays 2, 6 and 9 (NSRI-O, BSR-3 (M) and Pure Mysore) possessed most of the recessive genes.

Standarized deviation graph of $\overset{\cdot}{W}r + \overset{\cdot}{V}r$ on $\overset{\cdot}{Y}r$ (Fig. 3) showed that the arrays 1, 3, 5, 9 and 10 (Nistari (M), Nistid (W), O_5, Pure Mysore and $R_1 S_1$) exhibited an excess of dominant genes but differed in that the dominance in arrays 1 and 9 (Nistari (M) and Pure Mysore) was due to an excess of negative genes and in arrays 3, 5 and 10 (Nistid (W), O_5 and $R_1 S_1$) was due to an excess of positive genes. Similarly the recurrent parents of arrays 2, 4, 6, 7 and 8 (NSRI-O, BSR-1 (W), BSR-3 (M), MBW-062 (D) and BSRI-83/3) possessed recessive genes of negative type. The minus value of correlation ($r = -0.268$) indicated the presence of excess positive dominant genes. The similar graph for shell weight (Fig. 4) indicated that the arrays 3, 5, 8 and 10 (Nistid (W), O_5, BSRI-83/3 and $R_1 S_1$) possessed dominant genes of positive nature. Parents of arrays 6, 7 and 9 (BSR-3 (M), MBW-062 (D) and Pure Mysore) possessed dominant genes which were negative in nature while the arrays 1, 2 and 4 (Nistari (M), NSRI-O and BSR-1 (W)) possessed recessive genes of negative type. A correlation between these two measurements exhibited the presence of excess positive dominant genes ($r = -0.059$).

The component of variations and their ratios could be seen in Table 3. For both cocoon and shell weight the dominance component $\overset{\cdot}{H}_1$ exhibited a higher magnitude than the additive component $\overset{\cdot}{D}$ indicating the predominant role of non-additive variation (Table 3). The term $(\overset{\cdot}{H}_1/\overset{\cdot}{D})^{1/2}$, measures the average degree of dominance over all loci. Here the value of $\sqrt{H_1/D}$ was higher than one, indicating over dominance. These results are in conformity with the results of Wr, Vr graph (Fig. 1). The ratio F and $1/2\overset{\cdot}{F}\sqrt{\overset{\cdot}{D}(\overset{\cdot}{H}_1 - \overset{\cdot}{H}_2)}$ was less than unity exhibited the presence of more recessive alleles in the parents. In case of shell weight, the value of $\sqrt{\overset{\cdot}{H}_1/\overset{\cdot}{D}}$ and $1/4(\overset{\cdot}{D}/\overset{\cdot}{H}_1)$ exhibited the existance of partial dominance. These results supported the results of $WrVr$ graph. The ratio $\overset{\cdot}{H}_2/4\overset{\cdot}{H}_1$ suggested the unequal distribution of the genes and the opposit is true for cocoon weight. The value of the ratio $\overset{\cdot}{h}^2/\overset{\cdot}{H}_2$ suggested that at least one group of dominant genes were involved in both cocoon and shell weight. The narrow and broad sense heritabilities were 24.73% and 59.19% for cocoon weight while 55.20% and 98.64% for shell weight.

DISCUSSION

Experimental results revealed that both additive and dominance components of genetic variation are important in the inheritance of the economic characters under consideration. Graphical analysis and component of variation exhibited more or less

similar information. Examination of the least square estimates of component of variation showed that the dominance component ($\hat{H}_1$) was greater than that of additive genetic component ($\hat{D}$) in both the characters. This finding corroborate with the results of other diallel experiments with silkworm, *Bombyx mori* L. (Krishnaswamy *et al.*, 1964; Jolly *et al.*, 1969; Mather & Jinks, 1971; Satenhalli *et al.*, 1989; Siddqui *et al.*, 1988; Sarkar *et al.*, 1991). Heritability estimates for the traits revealed the importance of both additive and non-additive genetic variation with the preponderance of latter. The fraction $\hat{h}^2/\hat{H}_2$ gave a very low values of 0.448 and 0.46356 for cocoon ans shell weight respectively which indicated that only one dominant gene group was involved for these traits. The low estimation may be partly due to non-isodirectional distribution of positive and negative dominant genes (Cooke & Mather, 1962). The present finding concluded that the improvement of cocoon weight and shell weight may be obtained throught contemporaneous utilization of both additive and dominance variation by selection techniques in further generations. The pedgree method of selection may be used to achieve genetic progress of characters.

REFERENCES

Allard, R. W. (1956) The analysis of genetic environmental interactions by means of diallel cross, *Genetics* **41**: 305–319.

Cooke, P. and Mather, K. (1962) Estimating the component of continuous variation. II. *Genetical Heredity* **17**: 211–236.

Gamo, T., Otsuka, Y., Fujishima, T., Hirobe, T. and Tazima, Y. (1985) Estimation of combining ability and genetic analysis by diallel crosses between regional races of silkworm (I) Rearing performances and cocoon yields, *Tech. Bull. Seric. Expt. Sta.* **126**: 93–120.

Hayman, B. (1954) The analysis of variance of diallel table, *Biometrics* **10**: 235–244.

Jinks, J. L. and Hayman, B. L. (1953) The analysis of diallel crosses. *Maize Genet. News letter* **27**: 48–54.

Jinks, J. L. (1954) The analysis of continuous variation in a diallel cross of *Nicotiana rustica* L. varieties, *Genetics* **39**: 767–788.

Jinks, J. L. (1956) F_2 and backcrosses generation from set of diallel crosses, *Heredity* **10**: 1–30.

Jolly, M. S., Bardaiyar, V. N., Narasimhana, M. V. and Razdan, J. L. (1969) Diallel cross analysis of quantitative characters of four races of Indian Tasar Silkworm, *Antheraea mylitta* D. *Indian J. Seric.* **8**: 25–34.

Johnson, L. P. V. and Aksel, R. (1959) Inheritance of yielding capacity in a fifteen parent diallel cross of barley, *Can. J. Genet. Cytol* **3**: 242–357.

Krishnaswamy, S., Jolly, M. S. and Rao, S. S. (1964) Diallel analysis of quantitative characters in multivoltine races of silkworms, *Indian. J. Genet.* **24**: 213–222.

Mather, K. and Jinks, J. L. (1971) *Biometrical Genetics*, 2 Edition. Chapman & Hall: London.

Rahman, S. M. (1994) Filament length inheritance in a six parent diallel cross in the silkworm, *Bangladesh J. Zool.* **22(2)**: 209–215.

Satenhalli, S. B., Govindan, R. and Goud, J. V. (1989) Genetic analysis of some quantitative tratits by diallel cross in silkworm, *Bombyx mori* L., *Sericologia* **29**: 333–342.

Sarkar, A., Das, N. K. and Das, B. C. (1991) A diallel cross analysis of the cocoon weight in the silkworm, *Bombyx mori* L., *Sericologia* **31(2)**: 301–306.

Siddqui, A. A., Sengupta, A. K., Kumar, A., Moha Patra, D. P. D. and Sengupta, K. (1988) Studies on the genetic architecture and gene actions involving yield and yield components in diallel populations of tropical tasar silkworm, *Antheraea mylitta* D., *Sericologia* **98(1)**: 107–113.

Ecobiology of *Pseudacarapis indoapis* (Acari: Tarsonemidae)-1. Nutrition, Dispersal and Host range

K. Sumangala

*Department of Zoology, Zamorin's Guruvayurappan College,
Calicut, Kerala, 673014, India*

ABSTRACT: *Pseudacarapis indoapis* Lindquist is a tarsonemid mite associated with the Indian honeybee *Apis cerana* Fabr. Entire population of this mite occurs in beehives. The mite feeds on stored provision or fungus within the beehives and hence cleptoparasitic. Incidence of the mite was observed in *A. cerana* colonies throughout the year. However, the species was never encountered in hives/bees of any other species of *Apis* screened. Males and larvae were found restricted to beehives while females were also found phoretically associated with worker bees. They exhibited preferential attachment to posterior tentorial pits of the bees and bilateral distribution on host body. Number of individuals per bee ranged from two to fourteen. © 1999 Association for Advancement of Entomology

KEYWORDS: *Pseudacarapis indoapis*, cleptoparasite, phoresy

INTRODUCTION

Beehives represent an enchanting site with plenty of stored food materials, being exploited by an array of organisms ranging from microbes to man. Among the invaders of beehives, mites constitute a major group with respect to their biodiversity as well as types of interaction with the bees (Eickwort, 1988; Sumangala and Haq, 1999). Mites inhabit beehives either as permanent guests (Eickwort, 1988) or as occasional visitors (DeJong *et al.*, 1982). More than 100 species of mites have been reported from beehives from different parts of the world (Delfinado-Baker *et al.*, 1989; Eickwort, 1994; Kumar and Kumar, 1995; Sumangala and Haq, 1999). A recent survey on the mite fauna associated with honey bees in Kerala has yielded more than 25 species of mites from this habitat. Of these, 21 species have been encountered in colonies of *A. cerana* (Sumangala and Haq, 1999), the indegeneous honeybee being mainly employed in apiculture industry in this region. Among the acarine associates of *A. cerana*, the tarsonemid mite, *P. indoapis* represented a dominant species in terms of distribution and abundance. In addition to this, the mite appeared to be associated with the transmission of TSB disease of *A. cerana* (Sumangala and Haq, 1999). Therefore, specific studies have been carried out on the eco-biological aspects of the species.

The present paper sheds light on nutrition, dispersal mechanism and hostrange of the species.

MATERIALS AND METHODS

All parts of bee colonies like hive debris, portions of brood comb, provision comb, old comb and adult bees were collected from hives of *A. cerana, A. dorsata, A. florea* and *A. mellifera*. The samples were screened under Wild M420 stereomicroscope for the presence of mites. Distribution and relative abundance of the adult females of *P. indoapis* on body parts of worker bees was enumerated on samples of bees from different colonies. Attachment mechanism of the mite on bees was studied by introducing individual bees in laboratory cultures of the mite and making close observation on movement of the mites on various parts of the bees.

RESULTS AND DISCUSSION

Incidence of *P. indoapis* was recorded in samples of bees and hive materials of *A. cerana* collected from 14 localities of Kerala and southern parts of TamilNadu. Interestingly, this has turned to be the record incidence for a single species of mite made out during the study. Samples of hive debris, old combs, brood combs, provision combs as well as worker bees revealed the presence of this mite indicating its occurrence in all parts of the colonies. Earlier knowledge on the occurrence and distribution of this species is limited to a single report of the females on *A. cerana* bees from an unspecified locality in India (Lindquist, 1968, 1986). However the present study has envisaged the prevalence of the mite in *A. cerana* colonies in the area surveyed, suggesting its wide distribution in association with this bee. Detection of male and larval forms of *P.indoapis* made during the study added new information to the knowledge on morphology and systematics of the species, as these forms were not known so far. All life stages of *P. indoapis* were found in the hive materials, while the bees harboured only females. This has revealed the restricted distribution of the developing stages and males in the beehives.

Both adults and larval forms of the mite were very active and fast moving. In samples of old combs the individuals were found nibbling the fungal encrustations in empty cells. However, they were found consuming stored pollen grains in provision cells. Occasionally, the larvae were found entering cells with nectar also. Microscopic examination of the gut contents of the individuals revealed presence of partially digested pollen grains, fungal hyphae and spores, confirming the ingestion of these materials by the mites. This in turn suggests the cleptoparasitic status of this species in beehives. *Neocypholaelaps* spp. and *Carpoglyphus* spp. representing Mesostigmata and Astigmata respectively are the cleptoparasitic mites of beehives reported so far. (Eickwort, 1994). The present study has revealed similar status of Prostigmata in beehives.

In laboratory cultures, introduction of worker bees elicited response on female mites, which readily gained access to the bees. These mites were found contacting

the legs of the bees initially. Within few minutes the mites crawled to other regions of the bee body. Posterior tentorial pits, neck, wing base, thorax and abdomen were found to be the final attachment positions of the mites. Interestingly, the males and larvae never made contact with the bees. Observation of the attached females on bee body has helped to reveal the attachment mechanism of the former on the latter. The individuals were found using the elongated terminal pair of setae on tibiotarsus of leg IV for holding the hairs or edges of chitinous plates on the host body. Such an active association helps the mite to reach new destinations. Phoresy by females is considered to be the main mode of dispersal in tarsonemid mites (Lindquist, 1986).

Analysis of the samples of bees collected from various colonies of *A. cerana* indicated preferential attachment of *P. indoapis* on different parts of the host body. Distribution and relative abundance of the female *P. indoapis* on samples of the bees from five colonies of *A. cerana* is presented in Fig. 1. More than 80% of these phoretic individuals have been collected from the tentorial pits of the bees suggesting high degree of attachment specificity of the mite. Accordingly post tentorial pits of the bee were found to be most preferred site of attachment, followed by neck. All the remaining sites harboured almost equal percentage of mites. Existence of such preferential attachment among phoretic mites on their bee hosts has been recognized in several cases (Cross and Bohart, 1969; Delfinado-Baker *et al.*, 1992). This has been attributed to be an attempt by the mites to minimise dislodging during grooming activities of the host bee (Delfinado-Baker *et al.*, 1992). Usually the mites were found following bilateral symmetry during attachment to the host, which resulted in equal distribution of the mite density on either side of the worker bee. While discussing symmetric distribution of phoretic mites on alkali bee *Nomia melanderi*, Cross and Bohart (1969) have suggested that such arrangement of mites will help to maintain a balanced load on the bee, thereby minimising aerodynamic influence during flight. The frequency distribution of *P. indoapis* on the worker bees is illustrated in Fig. 2. The total number of mites collected from individual bees ranged from one to fourteen. Most of them harboured one to two mites.

Incidence of *P. indoapis* on worker bees and hives of *A. cerana* is evident during all seasons of the year. This has indicated the permanent association of the species with *A. cerana*. Generally phoretic females of tarsonemid mites are reported to be specific to a genus or family of insect hosts that live in specific habitats, which they use as a breeding ground (Lindquist, 1986). In the light of this generalisation, phoretic behaviour of *P. indoapis* females appeared to be very interesting, as they are found to be highly host specific on *A. cerana* workers. None of the other apid bees screened during the current study have recorded these mites on them. In addition to this, total absence of any life stage of this mite in colonies of these bees during the entire period of the study has provided further support for postulating the host specificity of *P. indoapis* on *A. cerana*. Therefore more intensive studies on the phoresy of *P. indoapis* on worker bees of *A. cerana* are warranted for evaluating the exact status of the phoretic association of the mite with this honeybee.
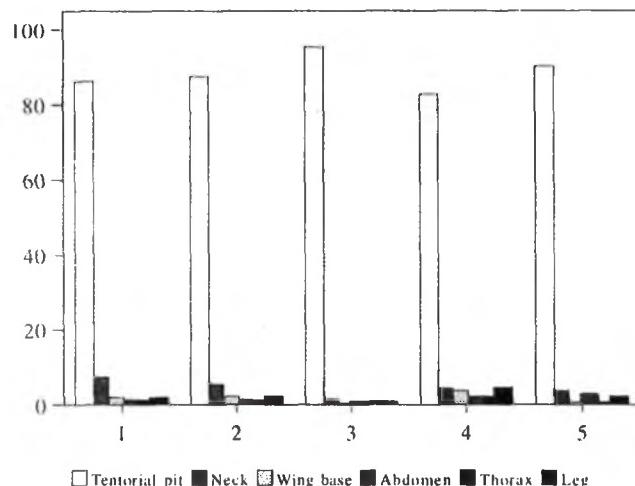
FIGURE 1. Distribution and relative abundance of female *P. indoapis* on *A. cerana* bees (in %).
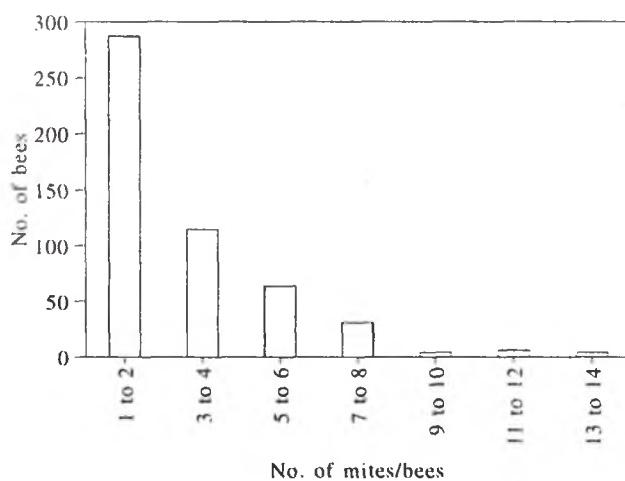
FIGURE 2. Frequency distribution of *P. indoapis* infestation on *A. cerana* workers.

ACKNOWLEDGMENT

this study. Further I express my sincere thanks to Prof. M. A. Haq, Division of Acarology, Department of Zoology, University of Calicut, for providing laboratory facilities for the study.

REFERENCES

Cross, E. A. and Bohart, G. E. (1969) Phoretic behaviour of four species of alkali bee mites as influenced by season and host sex, *J. Kans. Entomol. Soc.* **42(2)**: 195–219.

DeJong, D., Morse, R. A. and Eickwort, G. C. (1982) Mite pests of honeybees, *Ann. Rev. Entomol.* **27**: 229–252.

Delfinado-Baker, M., Baker, E. W. and Phoon, A. C. G. (1989) Mites (Acari) associated with bees (Apidae) in Asia, with description of a new species, *Am. Bee J.* **129(9)**: 609–610–612–613.

Delfinado-Baker, M., Rath, W. and Boeking, O. (1992) Phoretic bee mites and honeybee grooming behaviour, *Int. J. Acar.* **18(4)**: 315–322.

Eickwort, G. C. (1988) The origins of mites associated with honeybees. In: *Africanised bees and bee mites*, Needham, G. R., Page(Jr.), R. E., Delfinado-Baker, M. and Bowman, C. E.: (Editors). Ellis Horwood series in Entomology and Acarology: 327–338.

Eickwort, G. C. (1994) Evolution and life-history patterns of mites associated with bees. In: *Mites, Ecological and evolutionary analysis of life-history pattern*, Marylin, A. H.: (Editor). Chapman and Hall Publ. Inc.: New York, 218–251.

Kumar, R. and Kumar, N. R. (1995) Mites in close environment of honeybees, *Insect Envt.* **1(2)**: 5–7.

Lindquist, E. E. (1968) An unusual new species of *Tarsonemus* (Acarina, Tarsonemidae) associated with the Indian honeybee, *Can. Ent.* **100**: 1002–1006.

Lindquist, E. E. (1986) The world genera of Tarsonemidae (Acari: Heterostigmata). A morphological, phylogenetic and systematic revision with a reclassification of family group taxa in Heterostigmata, *Mem. Ent. Soc. Can.* **135**: 1–157.

Sumangala, K. and Haq, M. A. (1999) Survey on mite fauna associated with *Apis* spp. in Kerala, Southern India, In: *Proceedings of X Int. Congr. Acar.*, CSIRO Entomology: Canberra, (in press).

Nutritional Influence of Prey on the Predatory Potential and Reproduction of *Sycanus collaris* Fabricius (Reduviidae: Heteroptera)

S. Venkatesan *[1], R. Seenivasagan[2] and G. Karuppasamy[2]

[1]*Fredrick Institute of Plant Protection and Toxicology, Padappai, 601301, India*
Email: fippat@giasmd01.vsnl.net.in
[2]*Entomology Research Institute, Loyola College, Chennai, 600034, India*

ABSTRACT: Nutrient quality of prey insects such as *Spodoptera litura* (Noctuidae: Lepidoptera) and *Odontotermes obesus* (Termitidae: Isoptera) was observed to exert a direct influence on the growth and development of the pre-mated adults of *Sycanus collaris*. Accordingly, the reproductive performance and post embryonic development of the reduviid *S. collaris* were observed to depend on the biochemical composition of the prey insects. Maximum fecundity of *S. collaris* being higher when fed on the larvae of *S. litura*. Variation in the life table parameters of the predator was also observed on the two different prey species. The intrinsic rate of population increase being maximum when reared on *S. litura* with the generation time and population doubling time being shorter when fed on *S. litura* as compared on *O. obesus*. © 1999 Association for Advancement of Entomology

INTRODUCTION

One of the classical approaches in Integrated Pest Management (IPM) is augmentation of natural enemies, their mass rearing and release at appropriate stage and condition. Successful culturing of a suitable prey in the laboratory for rearing predators and parasitoids depends on the biology, behaviour and reproductive fitness of natural enemies. In order to augment this approach in biological control, increased attention needs to be diverted towards factors involved in successful predation, nutritional suitability as well as survivorship. Manipulation of these parameters leads to an effective utilization of natural enemies. The degree of prey specificity as well as feeding potential and subsequent physiological processes of insect natural enemies are regulated by the quality and quantity of nutrients of prey insects (Huffaker, 1958; Vinson, 1975; Venkatesan *et al.*, 1997).

*Corresponding author

Duration of the post embryonic development, fecundity, longevity and number of prey consumed during life time play a paramount importance in assessing the predatory efficiency of an individual (Ananthakrishnan, 1996). The predatory potential can be evaluated based on the number of prey killed per unit time by the predator. In predator-prey interactions, relatively low predation rate, delayed developmental period and high mortality of a polyphagous predator are due to inadequate nutrients available in the tissues of the prey insects (Salt, 1967). Predatory efficiency, reproductive potential can be monitored by inspecting the gut content and estimation of stored nutrients in the haemolymph and fat body (Miller and Silhacek, 1982). Chemical constituents of haemolymph vary significantly both quantitatively and qualitatively, depending upon the food (Ramdev and Rao, 1984).

The species of the reduviid predator namely *Sycanus* are found to be associated with a number of agriculture and plantation crop pests in India (Beeson, 1941; Nagarkatti, 1982; Patil and Thontadarya, 1983; Sundararaju, 1984; Ambrose and Paniadima, 1998; Venkatesan *et al.*, 1997, (unpublished data)). However, information on the role of nutrient quality of the prey species is scanty on the predatory and reproductive potential of *Sycanus collaris* (Reduviidae : Heteroptera). Hence, the present study concerns the feeding response and host selection of *S. collaris* on prey species such as the fall army worm, *Spodoptera litura* (Noctuidae : Lepidoptera) and the termite, *Odontotermes obesus* (Termitidae : Isoptera) which directly reflects utility of the predator in controlling the insect pests.

MATERIALS AND METHODS

Stock culture

The adults of *S. collaris* were collected from litter of shady trees along the cardomom ranges in Idukki District, Kerala, India. The stock culture of reduviids was reared in the laboratory condition (Temperature: 32 °C, Relative humidity: 75–85% and Photoperiod: 12 L: 12 D) for two generations on termites and larvae of *S. litura*. Different clutches of the reduviid eggs were kept seperately for hatching in the plastic containers (12 × 6 cm) with wet cotton swabs for maintaining optimum humidity.

The individuals obtained from the stock culture were used for experiments. Freshly hatched *S. collaris* nymphs were transferred into an insect rearing vial made of plastic of 250 ml capacity (8 × 7 cm). Nymphs numbering twenty were maintained separately on prey insects such as *S. litura* and *O. obesus*. After the second instar, the nymphs reared individually in a plastic vial (8 × 7 cm) on the respective prey insects to avoid cannibalism. Third instar larvae of *S. litura* were offered uniformly as prey for the entire life period of *S. collaris*. Observations on incubation period, nymphal duration, adult longevity and fecundity of *S. collaris* were recorded on its respective preys.

Prey density

Predators of both sexes were randomly selected from stock culture for prey density studies. For each experiment, the predator was placed singly in the petri-dish (10 cm)

with a wet cotton swab with either 2, 4, 8 numbers of larvae of *S. litura* or 8, 12, 16 numbers of the adults of *O. obesus* as prey. Ten replicates of each prey density were kept simultaneously. After 24 hours, the total number of prey attacked was counted.

Nutrient analysis

Collection of haemolymph and fat body

10 μl of haemolymph collected from the forelegs of premated male and female predatory insects into a tube containing 2 ml of 70% alcohol.

Fat body was dissected out and blotted on weighing paper. After weighing, 10 mg of fat body were homogenised with 3 ml of 70% alcohol. The fat body suspension was centrifuged and supernatant was used for the biochemical estimation.

Total carbohydrates (Dubois *et al.*, 1956), total proteins (Lowry *et al.*, 1951), free amino acids (Moore and Stein, 1948) and lipids (Folch *et al.*, 1957) were quantified in the whole body extract (70% alcohol) of prey insects, haemolymph and fat body of the predator.

Life-table studies

Cultures of *S. collaris* maintained in laboratory were used to study the life-table parameters. When nymphs reached the final instar on different prey insects, the reduviid cultures were monitored daily and newly eclosed adults were removed from the culture, paired with a member of the opposite sex and twenty five such pairs were thus observed. Data on egg laying (clutch) were recorded for each female. Life-tables were constructed following the procedure described by Birch (1948). The values of x, lx and mx were calculated using the formulae of Howe (1953).

RESULTS

Biology

The biological parameters such as incubation period, nymphal duration, adult longevity, pre-oviposition period and fecundity of *S. collaris* on *O. obesus* and *S. litura* are presented in Table 1. The incubation period of *S. collaris* was similar on both the prey species, however results on other parameters were not uniform. In general, nymphal duration was shorter when reared on *S. litura* larvae than on *O. obesus*. Maximum nymphal period was observed at IV and V instar stages on both the prey species. The longevity of both the sexes of *S. collaris* reared on *S. litura* was maximum compared to *O. obesus* ($P = 0.001$). Pre-oviposition period was high when *O. obesus* was offered as food. Regarding fecundity, more number of eggs were laid (105.67) by the female predator when reared on the larvae of *S. litura*.

Functional response

Almost equal number of preys were attacked by both the sexes of *S. collaris* in the initial one hour. The number of attacks on both the prey species in the initial one hour

TABLE 1. Biological data of *Sycanus collaris* reared on prey species

Parameters	Prey species	
	O. obesus	*S. litura*
Incubation period*	7.33 ± 0.52^a	7.17 ± 0.41^a
Nymphal duration**		
I Instar	7.40 ± 0.69^a	6.60 ± 0.51^b
II Instar	7.60 ± 0.52^a	6.30 ± 0.48^b
III Instar	8.80 ± 0.42^a	6.90 ± 0.57^b
IV Instar	16.60 ± 0.70^a	13.10 ± 0.99^b
V Instar	18.30 ± 0.82^a	14.40 ± 1.26^b
Total nymphal period	58.70 ± 1.06^a	$47.30 \pm .95^b$
Nymphal mortality	35%	20%
Longevity*		
Male	23.00 ± 1.73^a	31.83 ± 2.48^b
Female	31.67 ± 3.01^a	45.17 ± 1.83^b
Preoviposition period*	17.33 ± 0.82^a	10.17 ± 1.17^b
Fecundity***	71.00 ± 3.00^a	105.67 ± 5.69^b

(* −6 replicates;   ** −10 replicates;   *** −3 replicates)
Values followed by similar superscripts "across a row" are not
significantly different at 0.001% level.

TABLE 2. Predatory potential of *S. collaris*

Prey species	Number of prey given	Number of prey attacked/day		significant diffe- rence at % level
		Female	Male	
	2	2.00 ± 0.00	2.00 ± 0.00	NS
S. litura	4	3.80 ± 0.42	3.20 ± 0.42	0.01
	8	5.50 ± 0.53	4.30 ± 0.48	0.001
Significant at % level		0.001	0.001	
	8	7.60 ± 0.52	5.70 ± 0.48	0.001
O. obesus	12	9.00 ± 0.82	7.40 ± 0.52	0.001
	16	12.00 ± 0.67	9.60 ± 0.70	0.001
Significant at % level		0.001	0.001	

was fairly consistent with nearly all predators attacking atleast one prey. Minimum of two numbers of third instar larvae of *S. litura* was consumed daily (24 hours) by both the sexes of reduviid species (Table 2). When density of the prey *S. litura* larvae increased, consumption potential of female predator also increased correspondingly compared to the male predator and the difference was statistically significant ($P = 0.01, 0.001$). However, female predators consumed maximum number of *O. obesus* when compared to males ($P = 0.001$) despite no increase in prey density. Also, attacking rate of both the sexes increased as the prey density increased.
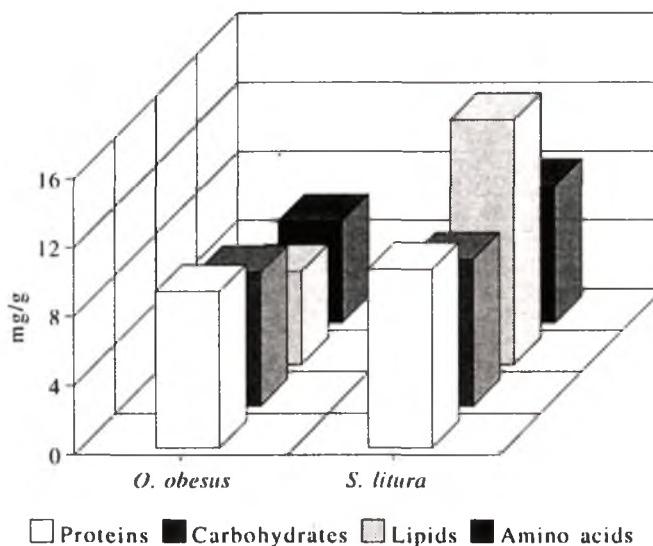
FIGURE 1. Biochemical estimations of whole body extract of *S. litura* and *O. obesus*.

Biochemical analysis

The reproductive performance and post embryonic development of predatory reduviid. *S. collaris* depend on the biochemical composition of prey insects. Maximum fecundity of *S. collaris* reared on *S. litura* was due to the increased quantity of proteins, carbohydrates, lipids and amino acids of *S. litura* (Fig. 1).

That the nutrient quality of the prey insects has a direct influence on the biochemistry of haemolymph and fat body of the insect predators, is evident from the results obtained on the biochemical profiles of fat body and haemolymph of the pre-mated male and female *S. collaris* on their respective prey insects (Table 3). The biochemical profiles of the fat body was relatively higher compared to haemolymph of the predator and the difference was statistically significant ($P = 0.001$). Quantity of protein in the fat body of female predator was minimum than the haemolymph collected from predators reared on two prey species. The levels of carbohydrates and amino acids in the fat body was higher than the levels in haemolymph. Quantity of proteins and amino acids in the fat body of male insect was higher than the female, however carbohydrate level in the fat body of females was maximum compared to male. The haemolymph of female predator had increased quantity of biochemical constituents than male insects.

TABLE 3. Biochemical profiles of the fat body and haemolymph of *S. collaris* reared on two prey species

Prey species	Sex	Proteins		Carbohydrates		Amino acids	
		Fat body (mg/g)	Haemolymph (mg/ml)	Fat body (mg/g)	Haemolymph (mg/ml)	Fat body (mg/g)	Haemolymph (mg/ml)
S. litura	Male	54.009 ±1.210	29.072 ±0.650	87.715 ±5.507	38.705 ±2.930	13.826 ±0.188	3.000 ±0.041
	Female	42.020 ±1.010	156.575 ±1.075	130.477 ±5.026	62.963 ±2.955	11.584 ±0.181	4.240 ±0.070
O. obesus	Male	42.638 ±2.660	26.425 ±0.585	49.100 ±1.875	22.592 ±2.296	11.907 ±0.210	2.755 ±0.054
	Female	27.990 ±2.560	52.780 ±0.805	104.445 ±5.453	31.110 ±1.720	9.166 ±0.097	3.242 ±0.066

Significant difference at 0.001% level.

TABLE 4. Oviposition pattern of *Sycanus collaris*

Number of clutches	Number of eggs per clutch		Difference at % level
	S. litura	*O. obesus*	
I	53.3 ± 4.04	38.3 ± 2.08	0.01
II	27.7 ± 1.53	20.0 ± 1.73	0.01
III	17.3 ± 0.58	9.0 ± 1.00	0.01
IV	5.3 ± 0.58	3.7 ± 0.58	0.05
V	2.0 ± 0.00	–	–

TABLE 5. Life-table statistics of *Sycanus collaris*

Parameters	Prey species	
	S. litura	*O. obesus*
Net reproductive rate (Ro)	30.46	12.06
Mean length of a generation (Tc)	41.01	78.91
Innate capacity for increase in numbers (rc)	0.008	0.030
Corrected rm	0.066	0.043
Corrected generation time (T)	51.82	57.91
Finite rate of increase in numbers (λ)	1.0682	1.0439
Weekly multiplication	1.5872	1.3512
Doubling time (Days)	10.561	16.096

Oviposition pattern

In addition to the variation in the biological data of *S. collaris* on prey insects, dissimilar pattern of oviposition was observed (Table 4). Five egg clutches were observed when reared on *S. litura*, while it was four on *O. obesus* with the maximum number of eggs being laid in the first oviposition of the predator. Difference in the number of eggs laid by *S. collaris* when fed on both prey species was statistically significant ($P = 0.01, 0.05$).

Total nymphal period and nymphal mortality was 49 days and 20% respectively when the larvae of *S. litura* was offered as food whereas, 60 days of nymphal duration and 35% of mortality was observed on *O. obesus*.

Life table studies

Variation in the life-table parameters of *S. collaris* was noticed on the two different prey species. Mean length of generation time of the predator was shorter when fed on *S. litura* (41.01 days) than *O. obesus* (78.91 days) (Table 5). Also, net reproductive rate (Ro) was maximum on *S. litura* when compared to *O. obesus*. Besides, the intrinsic rate of population increase was maximum on *S. litura* (Fig. 2). Hence, generation time (51.82 days) and the population doubling time (10.56 days) were shorter when fed on *S. litura* than on *O. obesus*.
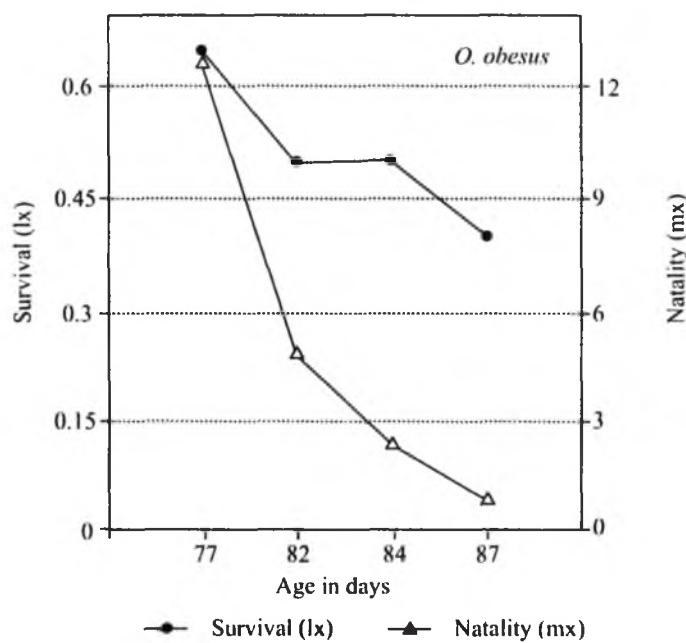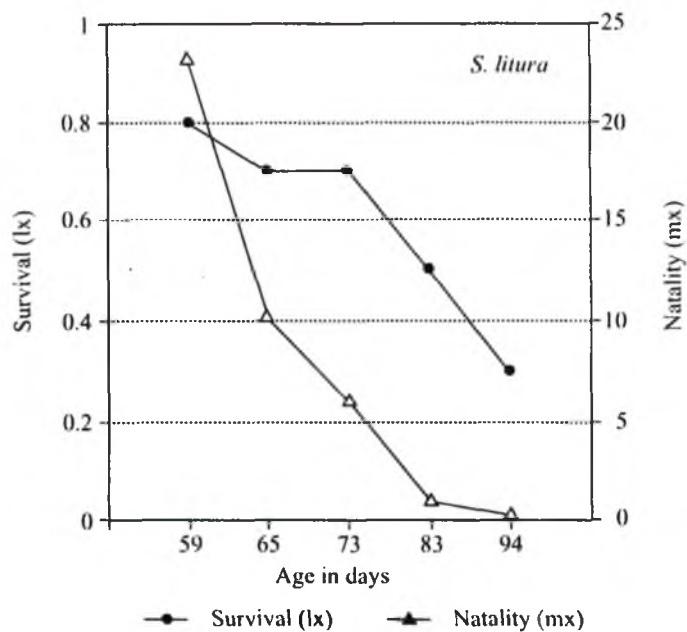
FIGURE 2. Survival (*lx*) and natality (*mx*) of *S. collaris* reared on two prey species.

DISCUSSION

Total nymphal duration and nymphal mortality of *S. collaris* was minimal when fed on the larvae of *S. litura*, possibly due to the reduced stress developed during predation and larger size with richer body tissue of prey insects. That, prey size and quality as well as quantity of nutrients of prey species not only influences the functional response of the predator (Holling *et al.*, 1976), but also on the feeding efficiency and reproductive potential (Beddington, 1975) is well known.

In coccinellid predators, viz. *Chilochorus bijugus, C. nigritus* and *Sticholotis madagassa* significant variation in the developmental period was observed on aphid hosts. However, *C. nigritus* which completed the development in shortest time on all the aphid species and to be considered as a potential predator (Jalali and Singh, 1989). Prolonged feeding time by *S. collaris* on *O. obesus* is one of the possible factors which enhance the nymphal duration of the predator. Observations on the maximum feeding time of *Lyctocoris campestris* on *Trogoderma variable, Trichoplusia ni* and *Rhyzopertha dominica* showed prolonged developmental period, pre-oviposition period and delayed reproduction (Parajulee and Phillips, 1993). Similarly, Stride (1956) noticed that feeding preference of *Phonoctonus lutescens* was maximum on *Odontopus sexpunctatus* as compared on *Dysdercus voelkeri*. Larvae of *Heliothis armigera* were better preferred by *Sycanus versicolar* when compared to *E. insulana* due to maximum level of primary nutrients (Kumaraswami and Ambrose, 1992).

Based on the prey density, functional response of the predator may be linear increase (Type I); an increase decelerating to a plateau (Type II); sigmoid increase (Type III) and a dome-shaped response (Type IV) (Holling, 1959; Tostowaryk, 1972; Hassell, 1978; Luck, 1985). Predatory potential of *S. collaris* showed type II functional response because no marked difference in feeding as prey density increased in all 24 hours of encounter, which exhibited similar results on the functional response of other reduviid species (Bass and Shepard, 1974; Ambrose and Kumaraswami, 1990).

Nutritional quality of the prey insects directly influence the metabolic processes in haemolymph and fat body tissues of insect predators which inturn pose an impact over various physiological events particularly the reproduction. Increased turnover of protein in the haemolymph of pre-mated females of *S. collaris* when reared on two prey species could possibly be due to synthesis of yolk proteins in the fat body which transports to haemolymph and preferentially accumulate for the oocyte development (Telfer, 1960; Srdic *et al.*, 1979; Hames and Bownes, 1970; Engelmann, 1979). Minimum level of carbohydrates observed in the haemolymph of both the sexes of the predator was aggreable with the results of Ludwig and Ramazzoto (1965). A steady fall in the concentration of glycogen in the haemolymph of *Tenebrio molitor* due to its mobilisation in the metabolic cycle for energy supply for its development of reproductive system and embryo (Chippendale, 1985). A wider variation in the fecundity of *S. collaris* was agreeable with the observation of Haque and Islam (1982), where the number of eggs laid by *Menochilus sexmaculatus* was maximum on the adults of *Myzus persicae* compared to *Schizaphis graminum* provided as food.

Prey species have a pronounced effect on both survivorship and differential patterns

of oviposition of predators. Natality and survivorship curves reflected the higher net reproductive rate of *S. collaris* on the larvae of *S. litura* when compared to *O. obesus*. The survivorship of nymphal population of *L. campestris* significantly reduced on *T. variable* and *T. ni* (Parajulee and Phillips, 1992). Similarly, Parajulee and Phillips (1993) noticed that net reproductive rate of *L. campestris* was maximum on pyralids than on *T. ni*. Hence, the present investigation suggests that considerable attention to be given to the quality and size of the prey species of a polyphagous predator when considering biological control efforts on a practical basis.

ACKNOWLEDGEMENTS

REFERENCES

Ambrose, D. P. and Kumaraswami, N. S. (1990) Functional response of the reduviid predator *Rhinocoris marginatus* Fabr. on cotton stainer *Dysdercus singulatus* Fabr. *J. Biol. Control.* **4(1)**: 22–24.

Ambrose, D. P. and Paniadima, A. (1998) Biology and behaviour of a harpactomine assassin bug *Sycanus pyrrhomelas* Walker (Hemiptera: Reduviidae) from South India. *J. Soil Biol and Ecol.* **8(1)**: 37–58.

Ananthakrishnan, T. N. (1996) *Forest Litter Insect Communities: Biology and Chemical Ecology*, Oxford and IBH Publishing Co. Pvt. Ltd.: New Delhi, 68.

Bass, J. A. and Shepard, M. (1974) Predation of *Sycanus indagator* on larvae of *Galleria mellonella* and *Spodoptera frugiperda*, *Entomol. Exp. Appl.* **17**: 143–148.

Beddington, J. R. (1975) Mutual interference between parasites or predators and its effect on searching efficiency. *J. Anim. Ecol.* **44**: 331–340.

Beeson, C. F. G. (1941) *Ecology and Control of Forest Insect Pests of India and Neighbouring Countries*, Reprint. Government of India: 67.

Birch, S. (1948) The intrinsic rate of natural increase in an insect populations, *J. Anim. Ecol.* **17**: 15–26.

Chippendale, G. M. (1985) Insect embryogenesis, morphology, physiology, genetical and molecular aspects, In: *Comprehensive Insect Physiology, Biochemistry and Pharmacology*, Kerkut, G. A. and Gilbert, L. I.: (Editors). Pergamon Press: Oxford, 319–385.

Dubois, M., Gilles, K. A., Hamilton, J. K., Rebers, P. A. and Smith, F. (1956) Colorimetric determination of sugars and related substances, *Anal. Chem.* **28**: 351–356.

Engelmann, F. (1979) Insect vitellogenin: identification, biosynthesis, and role in vitellogenesis, *Adv. Insect Physiol.* **14**: 49–108.

Folch, J., Less, M. and Sloane-Stanley-Stanley, G. H. (1957) A simple method for the isolation and purification of total lipids from animal tissues, *J. Biol. Chem.* **226**: 497–506.

Hames, B. D. and Bownes, M. (1970) Synthesis of yolk proteins in *Drosophila melanogaster*, *Insect Biochem.* **8**: 328–329.

Hassell, M. P. (1978) *The Dyanamics of Arthropod Predator-Prey Systems*, Princeton University: NJ.

Haque, M. E. and Islam, M. A. (1982) Effect of three species of aphids as food on the fecundity of lady bird beetle, *Bangladesh J. Agric.* **3**: 373–376.

Holling, C. S. (1959) Some characteristics of simple types of predation and parasitism, *Can. Ent.* **91**: 385–398.

Holling, C. S., Dunbrack, R. L. and Dill, L. M. (1976) Predator size and prey size: presumed relationship in the mantid *Hierodula coarctata* Saussure, *Can. J. Zool.* **54**: 1760–1764.

Howe, R. N. (1953) The rapid determination of intrinsic rate of increase of an insect population, *Ann. Appl. Biol.* **40**: 134–155.

Huffaker, C. B. (1958) Experimental studies on predation: disposal factor and predator-prey oscillation, *Hilgardia* **27**: 343–383.

Jalali, S. K. and Singh, S. P. (1989) Biotic potential of three coccinellid predators on various diaspine host, *J. Biol. Control.* **3**: 20–23.

Kumaraswami, N. S. and Ambrose, D. P. (1992) Biology and prey preference of *Sycanus versicolar* Dohrn (Hemiptera : Reduviidae), *J. Biol. Control.* **6(2)**: 67–71.

Lowry, O. H., Rosebrough, W. J., Farr, A. L. and Randall, R. J. (1951) Protein measurements with folin phenol reagents, *J. Biol. Chem.* **193**: 263–275.

Luck, R. F. (1985) Principles of Arthopod Predation, In: *Ecological Entomology*, Huffaker, C. B. and Rabb, R. L.: (Editors). Wiley: New York, 497–530.

Ludwig, D. and Ramazzoto, L. J. (1965) Energy resources during embryogenesis of the yellow mealworm, *Tenebrio molitor*, *Ann. Ent. Soc. Am.* **58**: 543–546.

Miller, S. G. and Silhacek, D. L. (1982) The synthesis and uptake of haemolymph storage proteins by the fat body of the greater wax moth, *Galleria mellonella* (L.), *Insect Biochem.* **12**: 293–300.

Moore, S. and Stein, W. H. (1948) Photometric ninhydrin methods for use in chromatography of amino acids, *J. Biol. Chem.* **176**: 367–388.

Nagarkatti, S. (1982) The utilisation of biological control in *Heliothis* management in India, *Proceedings of International Workshop Management*, ICRISAT: Patancheru, Andhrapradesh, 159–167.

Parajulee, M. N. and Phillips, T. W. (1992) Laboratory rearing and field observations of *Lyctocoris campestris* (Heteroptera : Anthocoridae), a predator of stored-product insects, *Ann. Ent. Soc. Am.* **85**: 736–743.

Parajulee, M. N. and Phillips, T. W. (1993) Effect of prey species on development and reproduction of *Lyctocoris camperstris* (Heteroptera: Anthocoridae), *Environ. Entomol.* **22(5)**: 1035–1042.

Patil, B. V. and Thontadarya, T. S. (1983) Natural enemy complex of the teak skeletonizer, *Pyrausta machaeralis* Walker (Lepidoptera : Pyralidae) in Karnataka, *Entomon* **8(3)**: 249–255.

Ramdev, Y. P. and Rao, P. J. (1984) Biochemical changes in larval haemolymph of *Achaea janata* Linn, *Proc. Indian Nat. Sci. Acad.* **B50(2)**: 154–162.

Salt, G. W. (1967) Predation in an experimental protozoan population, *Ecol. Monography* **37**: 113–114.

Srdic, Z., Beck, R. H. and Gloor, H. (1979) Autonomous yolk protein synthesis in ovaries of *Drosophila* cultured in vitro, *Wilhelm Roux Archives of Dev. Biol.* **187**: 255–266.

Stride, G. O. (1956) On the biology of certain West African species of *Phonoctonus* (Heteroptera: Reduviidae), mimetic predators of the Pyrrhocoridae, *J. Entomol. Soc. South Africa.* **19**: 52–69.

Sundararaju, D. (1984) Cashew pests and their natural enemies in Goa, *J. Plan. Crops.* **12(1)**: 38–46.

Telfer, W. H. (1960) The selective accumulation of blood proteins by the oocytes of saturnid moths, *Biological Bulletin* **118**: 338–351.

Tostowaryk, W. (1972) The effect of prey defence on the functional response of *Podisus modestus* (Hemiptera: Pentatomidae) to densities of the sawflies *Neodiprion swainei* and *N. pratti* Banksianne (Hymenoptera: Neodiprionidae), *Can. Ent.* **104**: 61–69.

Venkatesan, S., Seenivasan, R. and Karuppasamy, G. (1997) Influence of Prey species on feeding response, development and reproduction of the reduviid, *Cydnocoris gilvus* Burm (Reduviidae : Heteroptera), *Entomon* **22(1)**: 21–27.

Vinson, S. B. (1975) Biochemical coevolution between parasitoids and their hosts. In: *Evolutionary Strategies of Parasitic Insects and Mites*, Price, P. W.: (Editor). Plenum Press: New York.

Estimation of Direct Selection Parameters in a
Diallel Set of Bivoltine Silkworm (*Bombyx mori* L.)

G. N. Malik*[1], M. A. Masoodi[2], A. S. Kamili[2] and M. Aijaz[1]

[1]*Division of Sericulture, Mirgund, S. K. University of Agricultural Sciences &
Technology, Post Box 674, G.P.O. Srinagar 190001, Kashmir, India*
[2]*Directorate of Research, S. K. University of Agricultural Sciences and Technology,
Shalimar Campus, Srinagar 191121, Kashmir, India*

ABSTRACT: Estimates of direct selection parameters (heritability and genetic advance) in a 12×12 diallel set of bivoltine silkworm (*Bombyx mori* L.) evaluated over a set of 3 environments indicated 5th age larval duration, cocoon weight and shell weight to be highly heritable in a broad sense followed by ERR (effective rate of rearing) as moderately heritable whereas, shell ratio was least heritable. Genetic advance was more than 10% for cocoon weight, shell weight, shell ratio and 5th age larval duration and less than 10% for ERR. 5th age larval duration, single cocoon weight and shell weight offer ample scope for improvement through simple phenotypic selection.
© 1999 Association for Advancement of Entomology

INTRODUCTION

Estimates of direct selection parameters viz. heritability and genetic advance serve as useful guide to the breeder to formulate effective breeding strategies for bringing about improvement in desired characters. Heritability broad sense, the ratio of genotypic variance to total i.e. phenotypic variance, indicates the extent to which improvement of a trait in a population is possible through selection (Robinson *et al.*, 1949). It is population specific measurement that determines relative contribution of genetic and environmental differences to the total phenotypic variation. High heritability alone is not sufficient for making selection in advanced generations unless accompanied by substantial amount of genetic gain (Johnson *et al.*, 1955). Genetic advance, improvement in mean genotypic value of selected individual over base population, is important to the breeder in selection programmes. The estimates of heritability & genetic advance are frequently used by breeders to achieve superiority in the performance of various metric traits. But such information on bivoltine silkworm is very scanty (Ashoka and Govindan, 1990). Since such information about bivoltine

*Corresponding author

silkworm breeds maintained at the Division of Sericulture, Mirgund, is totally lacking, the present study was, therefore, an attempt to obtain unbiased estimates of direct selection parameters by evaluating a 12 × 12 diallel set of promising & diverse silkworm breeds drawn from Germplasm Bank maintained at the Division of Sericulture. Since genetic parameters estimated from trials conducted at one place/environment tend to be biased upwards due to confounding of environment & genotype × environment variance with genotypic variance, the present investigation was undertaken under a set of 3 environments to obtain relatively unbiased estimates.

MATERIALS AND METHODS

12 diverse bivoltine silkworm (*Bombyx mori* L.) breeds viz. SKUAST-1, SKUAST-6, KA, NB4D2, C122, J122, J112, Changnaung, Yakwei, Chukwei, Sheiki and Azad were drawn from Germplasm Bank maintained at the Division of Sericulture, Mirgund and crossed in a diallel fashion (excluding reciprocals) to raise 66 F_1 hybrids. The resultant hybrids along with their parents (78 treatments in all) were evaluated over a set of 3 environments with 3 replications for each treatment. Each replication comprised 250 worms after 3rd moult. The studies were carried out at Research Extension Centre, Kathua (Central Silk Board) during February–March (Environment-1) and at the Division of Sericulture, Mirgund during April–June (Environment-2) and June–August, 1996 (Environment-3). standard rearing techniques suggested by Krishnaswami (1978) were followed in this study. Pooled data collected in respect of 5 traits (Table 2) were analysed by completely randomized block design (Snedecor and Cochran, 1979). Genetic estimates were calculated by following standard methods (Singh and Choudhary, 1977). Genetic advance was calculated at 5% selection intensity ($K = 2.06$).

RESULTS AND DISCUSSION

Mean squares (Table 1) due to treatments, environments and treatment × environment interaction was significant for all the 5 metric traits indicating existence of adequate variability among genotypes & significant contribution of environments in the expression of various metric traits. It also indicated that performance of treatments was not stable over environments. The differences among parents and among hybrids were also highly significant except among parents for effective rate of rearing (ERR). Thus ERR is less likely to respond to selection. For other traits there is a scope for improvement by simple phenotypic selection. Mean squares due to interaction of hybrids with environments were significant for all traits whereas, parent × environment interactions were significant for single cocoon weight & 5th age larval duration and non significant for rest of the traits, indicating that study in a wide range of environments is necessary. A perusal of genetic parameters (Table 2) indicated that the difference between GCV & PCV was maximum in shell ratio followed by shell weight confirming substantial effect of environment in the expression of these traits. The estimates of heritability broad sense were fairly high for 5th age larval duration (92.9%), cocoon weight (91.4%)

TABLE 1. Pooled Analysis of variance–mean squares

Source of variation	df	Single cocoon weight	Shell weight	Shell ratio	ERR	5th age larval duration
Environments	2	330226.2**	15036.1**	99.8**	7892.5**	36110.2**
Replications within environments	6	56.05	21.8*	7.3***	9.7	58.9***
Treatments	77	1186.5**	102.1**	11.4**	34.5**	291.7***
Parents	11	479.1***	68.7***	10.5***	8.4	375.9***
Hybrids	65	1023.7**	84.9**	11.0***	29.5**	231.1***
Parents vs Hybrids	1	19547.4***	1584.0***	49.3***	642.2**	3306.5***
Treatment × Environment	154	208.8**	21.33**	6.1**	12.3**	76.6***
Parent × Environment	22	133.9**	6.4	2.9	5.4	82.0**
Hybrid × Environment	130	181.7***	22.7**	6.6**	13.5**	75.2***
Parents vs Hybrid × Environment	2	2792.0**	98.0**	6.3**	8.5	103.4**
Error	462	36.0	8.8	3.2	6.7	7.2

*,** Significant at $P = 0.05$ and $P = 0.01$ respectively.

TABLE 2. Genetic parameters of some metric traits in a 12 × 12 diallel set of bivoltine silkworm (*Bombyx mori* L.)

Metric trait	Phenotypic Variance	Genotypic Variance	Phenotypic Coefficient of variation	Genotypic Coefficient of variation	Heritability (broad sense)	Genetic advance (% of mean)
Single cocoon weight	419.5	383.5	11.2	10.7	91.4	21.1
Shell weight	39.9	31.1	18.0	15.9	77.9	29.0
Shell ratio	5.9	2.7	12.8	8.7	45.7	12.0
Effective rate of rearing (ERR)	16.0	9.3	4.9	3.8	58.0	5.9
5th age larval duration	102.0	94.8	6.8	6.6	92.9	13.1

and shell weight (77.9%); moderate for ERR (58.0%) and low for shell ratio (45.7%). Maximum genetic advance was recorded for shell weight (29.0) followed by cocoon weight (21.1), 5th age larval duration (13.1) and shell ratio (12.0). ERR (5.9) recorded a low estimate of genetic advance. High heritability estimates for cocoon weight and shell weight have also been reported by Gamo and Hirabayashi (1983); Jeong *et al.* (1986) and Ashoka and Govindan (1990). However, Gosh *et al.* (1994) reported heritability estimates of 63.65% and 59.56% for male cocoon weights in two different seasons. Contrary to this Rangaiah *et al.* (1995) found shell ratio (84.6%) to be highly heritable followed by shell weight (72.70%). These workers obtained maximum Genetic Advance for shell weight. In the present investigation only 5th age larval duration, single cocoon weight & shell weight displayed high heritability accompanied with reasonable genetic advance indicating, thereby, genotypic variability to be a major component of phenotypic variability and possible operation of additive gene action. Hence selection of phenotypically superior individuals from the population would lead to improvement of these traits. Such a selection for shell weight has been emphasized by Rangaiah *et al.* (1995). Traits, shell ratio & ERR exhibited low to medium heritability and low genetic advance suggesting preponderant action of non-additive gene action. Hence hybridization and recurrent selection for these traits may be fruitful.

REFERENCES

Ashoka, J. and Govindan, R. (1990) Genetic estimates of quantitative traits in bivoltine silkworm, *Bombyx mori* L., *Mysore Journal of Agricultural Sciences* 24: 371–374.

Gamo, T. and Hirabayashi, T. (1983) Genetic analysis of growth rate and pupation rate of some quantitative characters by diallel cross in silkworm, *Bombyx mori* L., *Japanese Journal of Breeding* 33: 191–194.

Gosh, B., Dass, R. S. K., Nair, B. P., Chattopadyay, S., Sen, S. K. and Sengupta, K. (1994) Some genetic parameters in multivoltine silkworm, *Bombyx mori* L., *Entomon* 19 (3 & 4): 91–93.

Jeong, W. B., Chang, K. Y., Han, K. S., Kim, J. H., Ryu, K. D., Chung, H. Y. and Ryu, S. C. (1986) Estimation of heritability and genotypic correlation through diallel crosses of silkworm, *Bombyx mori* L., *Korean Journal of Sericulture Science* 28(2): 7–19.

Johnson, H. W., Robinson, H. F. and Comstock, R. E. (1955) Estimates of genetic and environmental variability in Soyabean, *Agronomy Journal* 47: 314–318.

Krishnaswami, S. (1978) *New Technology of Silkworm rearing*, Bull No 2. C. S. R. & TI: Mysore, 15–23.

Rangaiah, S., Govindan, R., Devaiah, M. C. and Narayanaswamy, T. K. (1995) Genetic studies for some quantitative traits among multivoltine races of silkworm, *Bombyx mori* L., *Mysore Journal of Agricultural Sciences* 29: 248–51.

Robinson, H. F., Comstock, R. E. and Harvey, P. H. (1949) Estimates of herita-bility and degree of dominance in corn, *Agronomy Journal* 41: 353–359.

Singh, R. K. and Choudhary, B. D. (1977) *Biometrical Methods in Quantitative Genetic Analysis*, Kalyani Publishers: Ludhiana, New Delhi, 304.

Snedecor, G. W. and Cochran, W. (1979) *Statistical Methods*, Jowa State Univ. Press: Ames, Alowa, 593.

Predator complex of the teak defoliator, *Hyblaea puera* Cramer (Lepidoptera: Hyblaeidae) in an intensively managed teak plantation at Veeravanallur, Tamil Nadu

J. Loganathan[*1] and P. M. M. David[2]

[1]*E.I.D. Parry (India) Ltd., Agritech Research Centre, 145/146, Devanahalli Road, Bangalore, 560049, India*

[2]*Department of Agricultural Entomology, Agricultural College and Research Institute, Killikullam, Vallanad, Tamil Nadu, 628252, India*

ABSTRACT: A detailed survey was made in an intensively managed teak plantation to understand the predator complex of defoliator, *Hyblaea puera* Cramer (Lepidoptera: Hyblaeidae). Seventeen species of spiders, five species of carabids, four species of bugs and eight species of birds were identified as predators on defoliator. Notable among them were carabid beetles. Among the five species of ground beetles recorded, *Calosoma maderae* var. *indicum* Hope was more abundant. However, another carabid species *Omphra pilosa* (Klug) appeared more potential than *C. maderae* var. *indicum* in terms of prey consumption.   © 1999 Association for Advancement of Entomology

KEYWORDS: Predator complex; teak defoliator; intensively managed teak plantation

INTRODUCTION

One of the major pests of teak, the defoliator *Hyblaea puera* Cramer (Beeson, 1941; Sudheendrakumar, 1986; Nair, 1988), can cause reduction in the Current Annual Increment (CAI) upto 44 per cent (Nair *et al.*, 1985). Several authors have worked on this pest to identify the natural enemies especially from natural forests (Beeson, 1941; Chatterjee and Misra, 1974; Misra, 1975; Basu Choudhury and Misra, 1981; Patil and Thontadarya, 1983; Zacharias and Mohandas, 1990). Sudheendrakumar (1986) compiled all the predators including carabids, reduviids, pentatomids, spiders and birds. However, no information is available on the predatory fauna in recent-origin intensively managed teak plantations, where *H. puera* is a very serious problem. We made an attempt in this study to identify the predators that occur in one of such plantations.

*Corresponding author

TABLE 1. Carabid catch in pit-fall traps

Month	*C. maderae* var. *indicum*		*O. pilosa*	*C. rayotus*	*C. angulatus*
	Adult	Grub	(Adult)	(Grub)	(Adult)
December '96					
1–15	9.92	1.00	1.25	0.00	0.09
16–31	11.42	0.57	0.50	1.92	0.09
January '97					
1–15	20.25	0.00	1.34	0.09	0.09
16–31	4.42	0.00	0.17	0.00	0.00
February'97					
1–15	5.17	0.00	0.00	0.00	0.00
15–28	5.17	0.00	0.00	0.00	0.00
Mean	9.39	0.26	0.54	0.34	0.05

TABLE 2. Predatory potential of carabids

Species	No. of defoliator larva consumed per beetle			
	per hour		per day	
	Mean	Range	Mean	Range
O. pilosa				
Male	5.40 ± 0.46	4–6	13.33 ± 0.73	8–18
Female	7.90 ± 0.52	6–10	20.43 ± 0.82	14–30
C. maderae var. *indicum*				
Male	2.80 ± 0.34	1–5	7.17 ± 0.44	5–12
Female	3.90 ± 0.37	2–6	11.42 ± 0.61	8–14

MATERIALS AND METHODS

The investigation was conducted in a 3-year old intensively managed teak plantation at Veeravanallur in 1996. Weekly sampling was made to collect the predators associated with the larvae and pupae of *H. puera*, both on teak foliage and on ground from leaf litter and top soil. A short-term survey was conducted between December, 1996 and February, 1997. The carabid beetles population was assessed by installing ten pitfall traps consisting of a 15 cm wide plastic funnel and a collection jar (10 cm diameter, 15 cm tall). The traps were so buried that the funnel rim was just at the ground level. Weekly counts were made on the number of beetles trapped in each trap. The predatory potential of female and male beetles was studied in the laboratory at Agricultural College and Research Institute, Killikulam. Ten each of male and female beetles were placed singly in petridishes (10 cm diameter). Each beetle was given 10–25 fourth instar defoliator larvae. Consumption rate was observed and predatory potential was assessed per hour and per day.

RESULTS AND DISCUSSION

Ground beetles were identified as effective predators on *H. puera* larvae. Five species of ground beetles preyed on defoliator larvae and pupae: *Calosoma maderae* var. *indicum* Hope, *Chlaenius rayotus* Bates, *Craspedophorus angulatus* Fab., *Omphra pilosa* (Klug) and *Oxylobus dekkanus* Andrews. Earlier Sudheendrakumar (1986) reported on predation by *Parena nigrolineata* on defoliator. Pitfall trap catches indicated that *C. maderae* var. *indicum* was most numerous of all the five species (Table 1). Adult beetle catch averaged 9.39 per trap each week. *O. pilosa* was second most common. Other three species were very rare. As these carabids were identified during the monsoon season, it is evident from the 3-month data that they were more abundant in December–January than in February, the average largest catch being 20.25 beetles per trap in early January. As many as 106.0 beetles could be trapped in a single trap at that time. Spence and Niemala (1994) also tried pitfall traps to know the population dynamics of carabid beetles in forests. Both adults and grubs of ground beetles actively foraged above ground in the debris and litter collecting not only the mature defoliator caterpillars that roamed about the soil surface in search for ideal pupation sites but also the defoliator pupae inside the tough cocoons. Adults of *O. pilosa* would cut the cocoons open with mandibles and thrust their head inside to devour the pupa. Same behaviour in pupal predation was also observed with grubs of *C. rayotus*. Laboratory investigation revealed that *O. pilosa* was more potential than *C. maderae* var. *indicum* in terms of defoliator larval consumption (Table 2). Females of both the species devoured more larvae than did males. Males of *O. pilosa* consumed 4–6 larvae per hour and 8–18 larvae per day. Its females killed 6–10 larvae per hour and 14–30 larvae per day. *C. maderae* var. *indicum* was fifty per cent less potential than *O. pilosa*. Males of the former consumed only 1–5 larvae per hour and 5–12 larvae per day, while females ingested 2–6 larvae per hour and 8–14 larvae per day.

A few heteropteran bugs preyed upon mature defoliator larvae. They included *Lophocephala guerini* Laporte (Reduviidae: Harbactoninae), *Acanthaspis pedestris* Stal. (Reduviidae: Acanthaspidinae) and *Eucanthecona furcellata* (Wolf) (Heteroptera: pentatomidae). Compared to carabids, assassin bugs were only fewer in number. *Acanthaspis pedestris* was a wingless species feeding on defoliator larvae in the debris. The pentatomid *E. furcellata* preyed on defoliator larva inside leaf folds on trees.

Many species of spiders were found to be predaceous on early instar larvae of defoliator. They were identified as presented in Table 3.

Spiders captured both early and late instar larvae of defoliator. Patil and Thontadarya (1983) recorded 38 species of spiders as predatory on teak skeletonizer *Eutectona machaeralis* from a forest in Karnataka. However, spiders occurred rather at low densities round the year, being more abundant in November–December when defoliator larval population was at its peak during the monsoon epidemic (Fig. 1).

Several species of birds were busy on teak foliage collecting the defoliator larvae during epidemic infestations. They were the common mynah, *Acridotheres tristis*;

TABLE 3. Spiders recorded from an intensively managed teak plantation.

| Species	Family
Araneus sp.	Araneidae
Argiope catenulata	Araneidae
Argiope pulchella	Araneidae
Clubiona sp.	Clubionidae
Clubiona pogonias Simon	Clubionidae
Cryptophora carrisae	Araneidae
Gasteracantha geminata Fab.	Araneidae
Lycosa sp.	Lycosidae
Lycosa pseudoannulata (Boisdual and Strand)	Lycosidae
Leucauae celebesiana Walckenaer	Araneidae
Neoscona theis	Araneidae
Oxyopes janus	Oxyopidae
Oxyopes rufisternum	Oxyopidae
Peucetia viridanus	Oxyopidae
Plexippus sp.	Salticidae
Plexippus paykulli (Audonon & Sanigny)	Salticidae
Thomisus sp.	Thomisidae
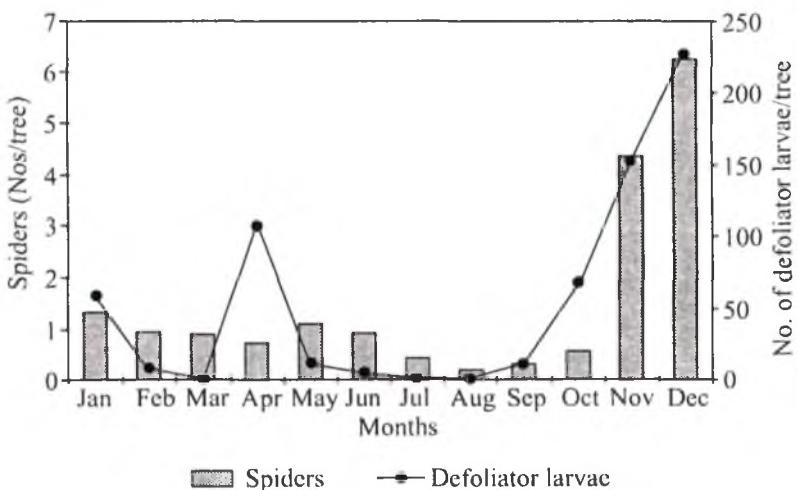
FIGURE 1. Spider population inrelation with defoliator infestation

king crow, *Dicrurus adsimilis*; jungle crow, *Corvus macrorhynchus*; common babbler, *Turdoides caudatus*; bee eater, *Merops* sp.; sun bird, *Nectarina* sp.; red vented bulbul, *Pycnonotus cafer* (Linnaeus); Paradise fly catcher, *Terpsiphone paradisi*. Teak plantation appeared a haven for the birds, especially during the epidemics. The

common mynah and the king crow were sighted more frequently than other birds. These birds actively collected defoliator larvae from teak foliage. Sudheendrakumar (1986) watched four species of birds to feed on defoliator larvae, while Zacharias and Mohandas (1990) recorded 58 species of birds in teak forests of Kerala, categorising them based on the feeding zones.

ACKNOWLEDGEMENT

REFERENCES

Basu Choudhury, J. C. and Misra, M. P. (1981) *Chlaenius rayotus* Bates (Coleoptera: Carabidae: Chlaeniini) - a new predator of *Hyblaea puera* Cramer from Walayar reserve forests, Kerala State, *Indian For.* **107(1)**: 63–65.

Beeson, C. F. C. (1941) *The Ecology and Control of Forest Insects of India and Neighbouring Countries*, Vasant press: Dehra Dun, 767.

Chatterjee, P. N. and Misra, M. P. (1974) Natural enemy and plant host complex of forest insect pests of Indian region, *Indian For. Bull.* **265**: 233.

Misra, R. M. (1975) Note on *Anthia sexguttata* F. (Carabidae: Coleoptera) a new predator of *Pyrausta machaeralis* Walker and *Hyblaea puera* Cramer, *Indian For.* **101(10)**: 605.

Nair, K. S. S., Sudheendrakumar, V. V., Varma, R. V. and Chacko, K. C. (1985) Studies on the seasonal incidence of the defoliators and the effect of defoliation on volume increment of teak, *KFRI Res. Report No. 30*, Peechi, 78.

Nair, K. S. S. (1988) The teak defoliator in Kerala, India, In: *Dynamics of Forest Insect Populations, Patterns, Causes, Implications*, Berryman, Alan A.: (Editor), 268–289.

Patil, B. V. and Thontadarya, T. S. (1983) Natural enemy complex of the teak skeletonizer, *Eutectona machaeralis* Walker (Lepidoptera: Pyralidae) in Karnataka, *Entomon* **8(3)**: 249–255.

Spence, R. and Niemala, (1994) Sampling carabid assemblages with pit fall traps: the madness and the method, *The Canadian Entomologist* **126**: 881–894.

Sudheendrakumar, V. V. (1986) Studies on the natural enemies of the teak pests, *Hyblaea puera and Eutectona machaeralis*, KFRI Res. Report No. 38. Peechi, 23.

Zacharias, V. J. and Mohandas, K. (1990) Bird predators of the teak defoliator *Hyblaea puera*, *Indian J. For.* **13(2)**: 122–127.

Effect of feeding mealy bug affected mulberry leaves (tukra) on nutritional efficiency and cocoon yield in the new bivoltine silkworm, *Bombyx mori* L.

C. A. Aftab Ahamed*, M. V. Chandrakala and V. G. Maribashetty

Karnataka State Sericulture Research and Development Institute, Thalaghattapura, Bangalore, 560062, Karnataka state, India

ABSTRACT: Mealy bug infestation of mulberry by *Maconellicoccus hirsutus* (Green) causes malformation of terminal buds and appearance of small curly leaves on the shoots. The food and dietary water intake and utilization were studied by feeding deseased mulberry leaves to the new bivoltine silkworms, *Bombyx mori* (Race: KSO₁) during fourth and fifth instars, caused shortening of the larval duration and significant increment in conversion rate, conversion efficiencies (K1 & K2), water absorption efficiency, water retained in the body and water retention efficiency. In continuation of this, a significant increase in larval biomass, cocoon, pupal and shell weights followed by their efficiencies were noticed inspite of lesser wet food consumed. The factors responsible for these beneficial changes in food and water intake and utilization are discussed. © 1999 Association for Advancement of Entomology

KEYWORDS: Bioenergetics, *Bombyx mori*, Silkworm, "Tukra"

INTRODUCTION

"Tukra" is a common problem in mulberry gardens caused by pink mealy bug, *Maconellicoccus hirsutus* (Green) (Hemiptera: Pseudococcidae) (Thangamani and Vivekanandan, 1983). *Morus alba* forms the basic food for the silkworm *Bombyx mori*. The efficiency in the amount of food required to reach its full potential will be manifested in various ways and degrees (Waldbauer, 1968). Nutritional efficiency in the larval stages significantly influences the resulting pupae, adult and production of silk particularly in the economically important insects like *B. mori* (Afatb Ahamed *et al.*, 1998). The infestation of mealy bugs causes morphological and anatomical changes in different plants, including mulberry, like curling of leaves, thickening and flattening of stems at the growing point (Sriharan *et al.*, 1979). At the time of de-saping, mealy bug penetrate their stylet in the tender parts of the plant, and the toxic saliva causes imbalance in the cell metabolism, which ultimately leads towards deformity and changes in morpho-histology of the plant parts with slight increase in stomatal number and size (Chatterjee *et al.*, 1993). In the present study, an effort has

*Corresponding Author

been made to examine the effect of feeding tukra affected mulberry leaves on food, dietary water intake and cocoon conversion efficiencies in the new bivoltine silkworms (Race: KSO_1) during fourth and fifth instar.

MATERIALS AND METHODS

The freshly moulted IV instar silkworm larvae (Race: KSO_1) were grouped in two batches with three replications (50 larvae/replication) and reared at temperature of $25 °C \pm 1 °C$ and $70 \pm 5\%$ relative humidity, as per the recommended method of Krishnaswami (1978). The experiment was initiated on the first day of fourth instar by feeding tukra affected mulberry leaves, to the silkworms of batch-I (Experimental) while, silkworms of batch-II (Control) received healthy mulberry leaves four times a day. Before feeding the fresh healthy and tukra affected mulberry leaves were cut in to two halves; one portion was used to find out the initial water content (Delvi and Pandian, 1972) and the other half was weighed and offered to silkworms. The quantity of leaf offered was similar in control and experimental batches. The left over leaves and litter of both the batches were weighed daily. Similarly, initial and maximum weight of IV and V instar larvae were recorded separately. All these samples including few larvae were dried to get constant weights to determine the dry weights. Daily food and dietary water intake and utilization were computed according to the method of Delvi (1983). The larval biomass, cocoon, pupae and silk conversion efficiencies were calculated based on their weights. The food and dietary water utilization parameters were statistically analyzed by adopting student 't' test.

RESULTS

The significant decrement is observed in larval duration by 12 hours in IV instar and by 24 hours in V instar, when the silkworm larvae fed on tukra affected mulberry leaves. The food intake was significantly decreased in the experimented batch and it amounts to 81% in IV instar and 80% in V instar when compared to the control (Table 1 & 3). Further, the quantity of defecation, food assimilated, food oxidized were higher in control batch but, in the experimental batch they are significantly lower during IV (Table 1) and V (Table 3) instar. However, the amount of food converted in to body substance in the experimental batch was found to be higher than the control during IV & V instars but not statistically significant (Table 1 & 3).

The rates of food/water intake and utilization are expressed in mg/mg live weight of insect/day. The feeding rate, assimilation rate and metabolic rate were significantly lower in the experimental batch during IV and V instar, whereas, the conversion rate and conversion efficiencies (K1 & K2) were significantly higher (Table 1 & 3) when compared with the control. However, the food assimilation efficiency in the silkworm larvae fed *ad libitum* on tukra affected mulberry leaves was on par with the control (Table 1 & 3).

The significant decrease in water intake was noticed in the experimental batch and it amounts to 92% in IV instar (Table 2) and 86% in V instar (Table 4). Similarly, the

TABLE 1. Influence of mealy bug affacted mulberry leaves on food intake and utilization in the new bivoltine silkworm *Bombyx mori* (Race: KSO_1) during IV instar

Sl. No.	Parameter	Control	Tukra	Student 't' Test
1.	Larval duration (D:H)	4 : 12	4 : 00	**
2.	Dry food consumed	783.8±2.6	636.6±1.3	**
3.	Faeces defecated	253.0±12.0	214.7±4.5	*
4.	Food assimilated	530.8±12.9	421.9±3.3	**
5.	Food converted	109.3±4.1	114.5±0.3771	N.S.
6.	Food oxidized	421.6±9.0	307.4±2.9	**
7.	Feeding rate	0.2887±0.0021	0.2465±0.0024	**
8.	Assimilation rate	0.1955±0.0049	0.1632±0.0017	**
9.	Conversion rate	0.0402±0.0014	0.0444±0.0004	*
10.	Metabolic rate	0.1552±0.0037	0.1190±0.0013	**
11.	Gross conversion efficiency (K_1)	13.9±0.4643	18.0±0.0816	**
12.	Net conversion efficiency (K_2)	20.6±0.3399	27.2±0.1247	**
13.	Food assimilation efficiency	67.7±1.6	66.3±0.6532	NS

Mean value, ±SD: The values of intake are expressed in mg/worm/instar.
The rates are expressed in mg/mg/day. The efficiencies are in percentage.
* Significant at 5%, ** Significant at 1%, NS: Non Significant

water loss through faeces, water absorbed, transpiration, water intake rate, water loss through faeces rate and transpiration rate were significantly lower in the experimental batch during IV (Table 2) and V (Table 4) instars but, the water absorption rate was on par with control. However, in the experimental batch the water absorption efficiency and water retention efficiency were significantly increased in IV and V instar (Table 2 & 4).

Further, in the experimental batch there is a significant increase in the larval biomass, cocoon, pupal and shell weights. However, the wet food consumed per larva was 12.0 gms in control and 10.2 gms in experimental batch during IV and V instars (Table 5). A highly significant increase in the conversion efficiency of wet food ingested to body matter, cocoon, pupa and shell were noticed in the silkworms fed *ad libitum* on tukra affected mulberry leaves when compared with control (Table 5).

When the parameters of food and dietary water budgets of IV and V instars were tabulated together, similar trend of decreased food consumption and increased conversion efficiencies (K1 & K2) and water retention efficiency was noticed (Figs. 1 to 6).

DISCUSSION

Insects have evolved a variety of strategies to acquire and accumulate energy from nutrients and water from the available food in a given environmental condition (Muthukrishnan and Pandian, 1987). The silkworm, *B. mori* being monophagous, derives almost all the nutrients essential for its growth from the mulberry leaf (Horie

TABLE 2. Influence of mealy bug affected mulberry leaves on dietary water intake and utilization in the new bivoltine silkworm *Bombyx mori* (Race: KSO₁) during IV instar

Sl. No.	Parameter	Control	Tukra	Student 't' Test
1.	Water intake	1620.5±5.5	1492.4±3.0	**
2.	Water loss through faeces	123.2±8.8	88.4±2.5	**
3.	Water absorbed	1497.3±10.4	1404.0±4.1	**
4.	Water retained in the body	636.8±8.4	709.2±12.5	**
5.	Transpiration	860.5±4.1	694.8±0.3771	**
6.	Water intake rate	0.5968±0.0044	0.5778±0.0057	*
7.	Water loss through faeces rate	0.0454±0.0031	0.0342±0.0007	**
8.	Water absorption rate	0.5144±0.0473	0.5436±0.0061	NS
9.	Transpiration rate	0.3170±0.0045	0.2690±0.0062	**
10.	Water absorption efficiency	92.4±0.5715	94.1±0.1699	*
11.	Water retention efficiency	42.5±0.3266	50.5±0.9177	**

Mean value, ±SD: The values of intake are expressed in mg/worm/instar.
The rates are expressed in mg/mg/day. The efficiencies are in percentage.
* Significant at 5%, ** Significant at 1%, NS: Non Significant

TABLE 3. Influence of mealy bug affected mulberry leaves on food intake and utilization in the new bivoltine silkworm *Bombyx mori* (Race: KSO₁) during V instar

Sl. No.	Parameter	Control	Tukra	Student 't' Test
1.	Larval duration (D:H)	7 : 00	6 : 00	**
2.	Dry food consumed	3453.6±83.0	2747.7±14.2	**
3.	Faeces defecated	1244.7±19.1	981.7±5.4	**
4.	Food assimilated	2208.9±85.1	1766.0±19.5	**
5.	Food converted	560.1±38.5	620.1±29.6	NS
6.	Food oxidized	1648.1±113.4	1145.9±34.7	**
7.	Feeding rate	0.2100±0.0093	0.1799±0.0029	*
8.	Assimilation rate	0.1343±0.0070	0.1156±0.0024	*
9.	Conversion rate	0.0340±0.0021	0.0406±0.0015	*
10.	Metabolic rate	0.1002±0.0080	0.0751±0.0032	*
11.	Gross conversion efficiency (K_1)	16.3±1.3	22.5±1.1	**
12.	Net conversion efficiency (K_2)	25.5±2.5	35.1±1.7	*
13.	Food assimilation efficiency	63.9±1.0	64.3±0.3682	NS

Mean value, ±SD: The values of intake are expressed in mg/worm/instar.
The rates are expressed in mg/mg/day. The efficiencies are in percentage.
* Significant at 5%, ** Significant at 1%, NS: Non Significant

and Watanabe, 1980). Till recently, tukra was referred as adisease since there was a belief that it was caused due to mycoplasmal or viral pathogens for which *M. hirsutus* served as a vector, but now tukra cannot be called as a disease due to the fact that neither of the aforesaid pathogen is involved in causing it (Manjunath *et al.*, 1993).

TABLE 4. Influence of mealy bug affected mulberry leaves on dietary water intake and utilization in the new bivoltine silkworm *Bombyx mori* (Race: KSO_1) during V instar

Sl. No.	Parameter	Control	Tukra	Student 't' Test
1.	Water intake	6139.7±147.5	5333.7±27.5	**
2.	Water loss through faeces	747.8±10.2	599.9±15.6	**
3.	Water absorbed	5391.9±147.1	4733.7±15.5	**
4.	Water retained in the body	1564.3±37.7	1746.1±42.5	*
5.	Transpiration	3827.7±160.8	2987.6±44.6	**
6.	Water intake rate	0.5968±0.0044	0.5778±0.0057	*
7.	Water loss through faeces rate	0.0454±0.0020	0.0393±0.0015	*
8.	Water absorption rate	0.3277±0.0150	0.3099±0.0042	NS
9.	Transpiration rate	0.2327±0.0129	0.1923±0.0078	*
10.	Water absorption efficiency	87.8±0.2944	88.7±0.2357	*
11.	Water retention efficiency	29.0±1.1	36.9±0.9031	**

Mean value, ±SD: The values of intake are expressed in mg/worm/instar.
The rates are expressed in mg/mg/day. The efficiencies are in percentage.
* Significant at 5%, ** Significant at 1%, NS: Non Significant

TABLE 5. Influence of mealy bug affected mulberry leaves on the larval and cocoon weights in the new bivoltine silkworm *Bombyx mori* (Race: KSO_1)

Sl. No.	Parameter	Control	Tukra	Student 't' Test
1.	Larval weight (g)	3.153±0.1614	3.898±0.0476	**
2.	Cocoon weight (g)	1.405±0.0108	1.690±0.0122	**
3.	Pupal weight (g)	1.130±0.0141	1.368±0.0062	**
4.	Shell weight (g)	0.2750±0.0108	0.3217±0.0094	*
5.	Wet food consumed/larva (g)	12.0±0.2206	10.2±0.0408	**
6.	Wet food ingested to larval biomass conversion efficiency (%)	26.27±1.2	38.18±0.4740	**
7.	Wet food ingested to cocoon conversion efficiency (%)	11.71±0.1558	16.55±0.1605	**
8.	Wet food ingested to pupa conversion efficiency (%)	9.41±0.0613	13.40±0.1109	**
9.	Wet food ingested to shell conversion efficiency (%)	2.29±0.1184	3.15±0.0927	**

* Significant at 5%

** Significant at 1%

In the present study it is observed that feeding tukra affected mulberry leaves to the new bivoltine silkworms (Race: KSO_1) influences the metabolic activities like food and dietary water intake and utilization parameters in a positive manner.

The shorter larval duration in the experimental batch is obviously due to feeding of tukra affected mulberry leaves, which has higher moisture content than the normal
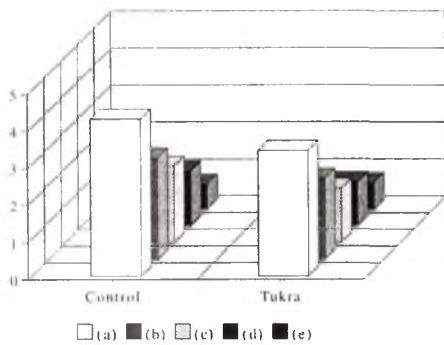
□(a) ■(b) □(c) ■(d) ■(e)
Fig. 1. (a) Food intake; (b) Food assimilated;
(c) Food oxidized; (d) Faeces defecated and
(e) Food converted.
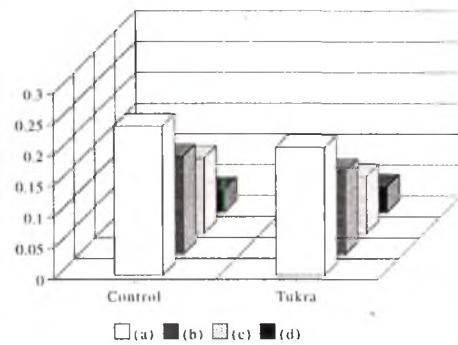
□(a) ■(b) □(c) ■(d)
Fig. 2. (a) Feeding rate; (b) Assimilation rate;
(c) Metabolic rate and (d) Conversion rate.
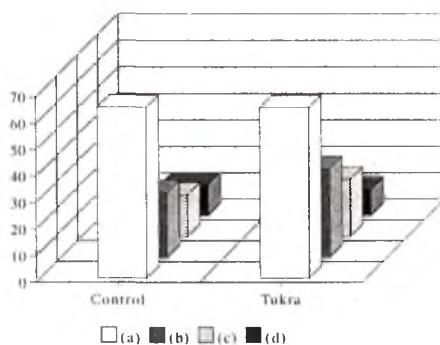

□(a) ■(b) □(c) ■(d)
Fig. 3. (a) Food assimilation efficiency; (b) Net
conversion efficiency (K_2); (c) Gross conversion
efficiency (K_1) (d) Larval duration (Days).

FIGURES 1–3. Influence of Mealy bug infested mulberry leaves on food budget in the new bivoltine silkworms during IV & V instars (Race : KSO_1).

healthy mulberry leaves (Thangamani and Vivekanandan, 1983; Umesh Kumar *et al.*, 1990) and higher nutritive value (Chatterjee *et al.*, 1993; Veeranna, 1997). The decrease in food consumption is due to shorter larval duration and silkworm larvae accumulate sufficient energy and nutrients to pupate successfully in the lesser period (Haniffa *et al.*, 1988). However, many lepidopterans exhibit consumption of increased food during extended larval period (Noor Pasha and Delvi, 1989; Afatb Ahamed *et al.*, 1998). Inspite of lower food consumption, defecation, assimilation and oxidation including rates, the food conversion into body substance is very high as seen by the conversion rate and conversion efficiencies (K1 & K2) in the silkworm larvae fed on tukra affected mulberry leaves. Further, this emphasizes that, better nutrient level was present in the tukra affected mulberry leaves, perhaps the decline in the quantity of mulberry leaf is not correlated with the quality (Pradeep *et al.*, 1992; Manjunath *et al.*, 1993).
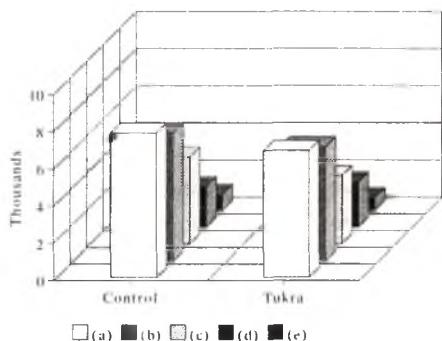
□(a) ■(b) ▨(c) ■(d) ■(e)
Fig. 4. (a) Water intake; (b) Water absorbed;
(c) Transpiration; (d) Water retained in the body
and (e) Water loss through faeces.
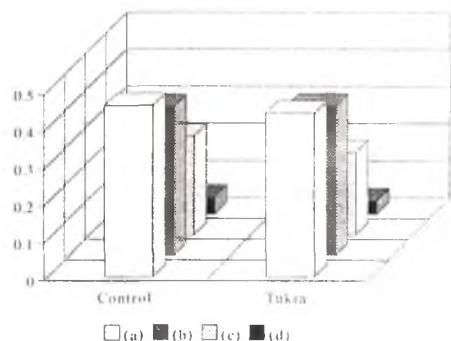
□(a) ■(b) ▨(c) ■(d)
Fig. 5. (a) Water intake rate; (b) Water absorption
rate; (c) Transpiration rate and (d) Water loss
through faeces rate.
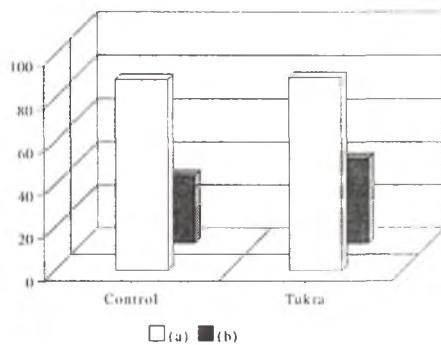
□(a) ■(b)
Fig. 6. (a) Water absorption efficiency and
(b) Water retention efficiency.

FIGURES 4–6. Influence of Mealy bug infested mulberry leaves on water budget during IV & V instars in
new bivoltine silkworms (Race : KSO_1).

It is known that the dietary water in silkworm nutrition has a major influence
on its performance (Reddy, 1981; Aftab Ahamed, 1994). The method and extent of
water intake and loss are complex and continuously changing phenomenon (Delvi
et al., 1988). The consumption of dietary water in silkworm has been shown to be
directly related to the moisture content of the mulberry leaf and the amount of food
intake (Shajahan Begum, 1992). In the present investigation low water intake in the
experimental batch must be due to reduction in the quantum of food intake (Aftab
Ahamed *et al.*, 1998). The close relationship of water and food utilization parameters
are well indicated in reduced absorption of water, loss through faeces, transpiration
including rates and increased retention of water. However, the insect maintained the
water balance by compensating the impact of feeding tukra affected mulberry leaf by
reducing the water loss through faeces, transpiration and increasing the efficiency of

water absorption and retention. Similar results in water balance with body have been reported by Afatb Ahamed *et al.* (1998), during deprivation of food in the silkworm *B. mori* (Race: Pure Mysore).

It is evident from the data obtained from the food and water budget of IV and V instars that feeding of mealy bug infested mulberry leaves influences the food and water utilization patterns along with cocoon and shell weights in the bivoltine silkworm race. The present investigation shows an increase in the conversion efficiency of food in to larval biomass. cocoon, pupa and shell, inspite of lesser wet food consumed. Similar results of higher conversion have been reported by Veeranna (1997), in the popular bivoltine silkworm race (NB_4D_2) when the larvae fed with tukra affected mulberry leaves from hatching to the end of caterpillar stage. Hence, when the mealy bug infested leaves were fed to silkworms, the efficiencies of food conversion and water retention increases, indicating better nutritional value, thus resulting in higher cocoon yield in the new bivoltine silkworm *B. mori* (Race: KSO_1).

ACKNOWLEDGEMENTS

REFERENCES

Afatb Ahamed, C. A. (1994) Effect of diseased mulberry leaves *Morus alba* on food and water utilization in the silkworm *Bombyx mori* L. Ph. D. Thesis, Bangalore University, 151.

Afatb Ahamed, C. A., Chandrakala, M. V., Shivakumar, C. and Raghuraman, R. (1998) Food and water utilization patterns under restricted durations in *Bombyx mori* of Pure Mysore race, *J. Exp. Zool. India* 1(1): 29–34.

Chatterjee, K. K. and Sarkar, A. (1993) Mealy bug infestation in mulberry, *Indian Silk* 31: 19–20.

Delvi, M. R. (1983) Dietary water balance in a tropical insect, *Proc. Indian Acad. Sci.* (Anim. Sci.) 92: 135–145.

Delvi, M. R. and Pandian, T. J. (1972) Rates of feeding and assimilation in the grasshopper*Poecilocerus pictus*, *J. Insect Physiol.* 18: 1829–1843.

Delvi, M. R., Radhakrishna, P. G. and Noor Pasha, (1988) Effect of leaf ration on dietary water budget of the larvae of silkworm, *Bombyx mori* and Eri silkworm, *Philosamia ricini*, *Proc. Indian Acad. Sci.* (Anim. Sci.) 97: 197–202.

Haniffa, M. A., Punitham, M. Thomas and Arunachalam, S. (1988) Effect of larval nutrition on survival, growth and reproduction in the silkworm, *Bombyx mori* L., *Sericologia* 28(4): 563–575.

Horie, Y. and Watanabe, K. (1980) Recent advances in Sericulture, *Ann. Rev. Entomol.* 25: 49–79.

Krishnaswami, S. (1978) *Bull. No. 2 (C.S.R & T.I: Mysore)*, 1–28.

Manjunath, D., Pradeep Kumar, Ramkishore, Satyaprasad, K., Narayanaswamy, K. C. and Datta, R. K. (1993) Towards understanding tukra and its managements, *Indian Silk* 31: 6–9.

Muthukrishnan, J. and Pandian, T. J. (1987) Relation between feeding and egg production in some insects, *Proc. Indian. Acad. Sci.* (Anim. Sci.). 96: 171–179.

Noor Pasha, and Delvi, M. R. (1989) Effect of starvation on the food utilization budget of Eri silkworm, *Philosamia ricini*, *Nutri. Ecol. Ins. Env.* **10**: 205–211.

Pradeep Kumar, Ramkishore, Noamani, M. K. R. and Senugupta, K. (1992) Effect of feeding tukra affected mulberry leaves on silkworm rearing performance, *Indian J. Seric.* **31**(1): 27–29.

Reddy, M. V. (1981) Relationship among water contents of food, faeces, body tissues of larvae of *Philosamia ricini*, (Saturnidae: Lepidoptera), *Comp. Physiol. Ecol.* **6**: 253–255.

Shajahan Begum, (1992) Influence of leaf water content on dietary water and food utilization in different races of silkworm, *Bombyx mori* L. M. Phill. Dissertation, Bangalore University, Bangalore, 104.

Sriharan, T. P., Sampson, M. V. and Krishnaswami, S. (1979) Studies on the tukra disease (*Maconellicoccus hirsutus*) of mulberry, *Indian J. Seric.* **18**: 78–80.

Thangamani, R. and Vivekanandan, M. (1983) Effective utilization of tukra diseased mulberry leaves as silkworm, *Bombyx mori* L. feed, *Sericologia* **23**: 211–223.

Umesh Kumar, N. N., Sree, M. P., Muthegowda, and Boraiah, G. (1990) Changes in proteins, sugars, phenols and total chlorophyll content of mulberry plants affected by "Tukra", *Indian J. Seric.* **29**: 93–100.

Veeranna, G. (1997) Biochemical changes of tukra leaves of mulberry and its effect on economic characters of mulberry silkworm, *Bombyx mori* L, *Entomon* **22**(2): 129–133.

Waldbauer, G. P. (1968) The consumption and utilization of food by insects, *Adv. Insect Phisiol.* **5**: 229–288.

Sexing of Adults of Coffee White Stem Borer, *Xylotrechus quadripes* (Chevr.) (Coleoptera : Cerambycidae)

M. G. Venkatesha[1] and H. G. Seetharama[2]

[1]*Department of Zoology, Bangalore University, Jnana Bharathi, Bangalore 560056, Karnataka, India*
[2]*Central Coffee Research Institute, Coffee Research Station, Chikmugulure - 577117, Karnataka, India*

ABSTRACT: The paper describes the morphological differences between the female and male adults of *Xylotrechus quadripes*. © 1999 Association for Advancement of Entomology

KEYWORDS: Sexing, *Xylotrechus quadripes*, morphology, *Coffea arabica*

The coffee white stem borer, *Xylotrechus quadripes* (Chevr.) is a serious pest of arabica coffee, *Coffea arabica* L. in India. The various studies such as screening of different insecticides in the laboratory and field (Anonymous, 1996–97) and use of sex pheromone (Jayarama and Venkatesha, 1995; Hall David *et al.*, 1998) are in progress for effective management of the pest. Sexing of white stem borer adults is important in the screening of insecticides and pheromone studies. Stebbing (1914) described the face of the adult male *X. quadripes* as having more or less distinct median carina, between which and each of the lateral carinae there is an elongated, very finely regulose, opaque black area, with slightly raised edges and hind femora extending beyond the apex of elytra whereas, face of the female as having a single raised line or carina on each side midway between the meadian and lateral carina and hind femora not reaching past the apex of elytra. However, our observations have revealed that every white stem borer adult can not be sexed based on the markings on the face and length of hind femora as variations of these characters have been noticed in several individuals. Therefore, a study was conducted to record the per cent variations of these two characters and other morphological differences in the male and female beetles of *X. quadripes*.

The white stem borer beetles of 1996 flight (emergence) periods were collected from the field infested stems and preserved in 70% alcohol for sexing observations. The male and female beetles were sexed as per the description of Stebbing (1914) and these adults were referred as distinguishable sexes. The adults that could not be sexed due to indistinct markings on the frons in which only median line was present and variation in length of hind femora with that of elytra were dissected and confirmed their sex based

Sexing of Adult of Coffee White Stem Borer

TABLE 1. Per cent variations of sexing characters in adults of *Xylotrechus quadripes*

Type of sexing characters	Sex	No. of adults		Per cent population		Total per cent population
		April–May	Oct.–Dec.	April–May	Oct.–Dec.	
♣ Face with median carina and opaque black area between median and lateral carinae & hind femora extend beyond the apex of elytra	Male	49	87	48.04	31.52	35.98
♣ Face with median carina and opaque black area between median and lateral carinae & hind femora not reaching past the apex of elytra	Male	1	5	0.98	1.81	1.59
♠ Indistinct markings on the face & hind femora extend beyond the apex of elytra	Male	2	24	1.96	8.70	6.88
♠ Indistinct markings on the face & hind femora not reaching past the apex of elytra	Male	1	12	0.98	4.35	3.44
♣ Face with single raised line on each side midway between the median and lateral carinae & hind femora not reaching past the apex of elytra	Female	43	117	42.16	42.39	42.32
♣ Face with single raised line on each side midway between the median and lateral carinae & hind femora extend beyond the apex of elytra	Female	1	3	0.98	1.09	1.06
♠ Indistinct markings on the face & hind femora not reaching past the apex of elytra	Female	4	27	3.92	9.78	8.20
♠ Indistinct markings on the face & hind femora extend beyond the apex of elytra	Female	1	1	0.98	0.36	0.53

♣ Distinguishable sexes
♠ Indistinguishable sexes
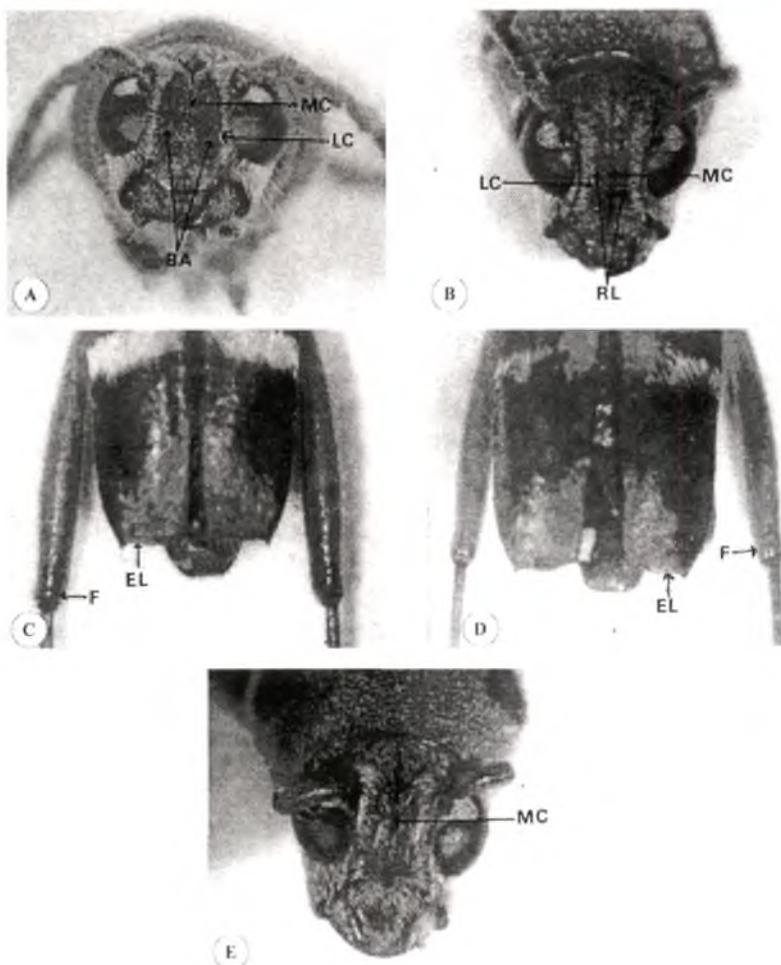
FIGURE 1. *Xylotrechus quadripes*, A. Frontal view of the head of the male beetle; B. Frontal view of the head of the female beetle; C. Posterior portion of the male beetle showing hind femoral length with that of elytra; D. Posterior portion of the female beetle showing hind femoral length with that of elytra; E. Frontal view of the head of the indistinguishable beetle. Terminology, BA – black area; EL – elytra; F – femur; LC – lateral carina; MC – median carina; RL – raised line.

on the presence of aedeagus or ovary and these were termed indistinguishable sexes. Furthermore, the length and width (across the thorax) of the adults were recorded. The size difference between the male and female beetles was statistically analyzed. The other morphological differences noticed in the male and female beetles were also recorded.
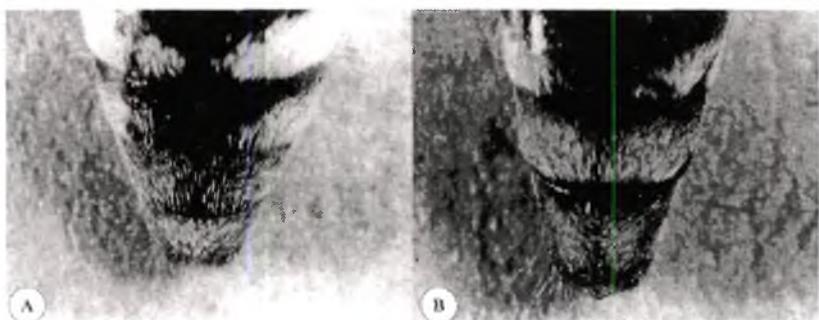
FIGURE 2. *Xylotrechus quadripes*, Ventral side of the posterior abdomen of the male (A) and female (B) beetles.

The observations made on the per cent variations in type of markings on the face and hind femoral length with that of elytra in *X. quadripes* male and female beetles are given in Table 1. The study revealed that in the total adult populations of two flight periods, the majority of males (35.98%) and females (42.32%) showed clear morphological characters as described by Stebbing (1914) (Fig. 1). In the rest of the population, 6.88% of males and 8.20% of females had indistinct markings on the face but their length of hind femora was similar to that described by Stebbing (1914).

These adults could be sexed by dissecting the abdomen and examining the presence of aedeagus or ovary. It was also noticed in the study that in 3.44% of males with indistinct markings on the face, hind femoral length was shorter than elytra as in distinguishable females and in 0.53% of females with indistinct markings on the face, length of hind femora were longer than elytra as in distinguishable males. In 1.59% of males with distinct markings on the face, hind femora were shorter than elytra as in distinguishable female and in 1.06% of females, hind femora were longer than elytra similar to that of distinguishable males. The examination of sex organs in these adults clearly indicated that the adults with distinct type of markings on the face could be sexed irrespective of the hind femoral length. However, the borer adults could not be sexed based on the hind femoral length alone as this is not a constant character with respect to sex in every individual of *X. quadripes*

Further observations on the morphological characters of the adults of both sexes have revealed that the ventral side of the last segment of the abdomen of female beetle is long and tapered with semicircular tip whereas, it is short and broad with slightly rectangular tip in males. Besides this, the last segment of the abdomen is slightly longer than that of preceding segment in females but, these two segments are almost equal in males (Fig. 2). The length and width of the male and female beetles of two flight periods are given in Table 2. The several females in a population of two flight periods were larger than males and mean size of females were significantly different from that of males ($P > 0.05$). However, females and males could not be differentiated based on the body size as range of size of both sexes coincide each other

TABLE 2. Measurements of *Xylotrechus quadripes* adults of different flight periods

Type	Flight period	Length of body (in mm) Mean (SD, Range, n)	Width of body (in mm) Mean (SD, Range, n)	Per cent Population
Distinguishable female	April–May	*A12.32 (±1.70, 9.50–16.00, 43)	*A2.91 (±0.54, 2.00–4.00, 43)	42.16
Distinguishable male	April–May	◆A11.03 (±1.42, 7.50–15.00, 49)	◆A2.66 (±0.44, 2.00–4.00, 49)	48.04
Distinguishable female	Oct.–Dec.	#B13.18 (±1.66, 9.00–19.00, 117)	#B3.18 (±0.53, 2.00–4.75, 117)	42.39
Distinguishable male	Oct.–Dec.	∞B12.07 (±1.61, 8.00–16.00, 87)	∞B2.84 (±0.43, 1.90–4.00, 87)	31.52
◆Indistinguishable female	April–May	*11.92 (±1.28, 10.50–13.00, 6)	*2.71 (±0.49, 2.00–3.25, 6)	5.88
◆Indistinguishable male	April–May	◆12.38 (±2.56, 10.00–16.00, 4)	◆2.88 (±0.63, 2.25–3.75, 4)	3.92
◆Indistinguishable female	Oct.–Dec.	#13.08 (±1.10, 10.50–16.50, 31)	#2.99 (±0.50, 2.00–5.00, 31)	11.23
◆Indistinguishable male	Oct.–Dec.	∞12.20 (±1.61, 9.50–17.00, 41)	∞2.83 (±0.42, 2.00–4.00, 41)	14.86

Results in a column followed by the same letter are significantly different at 0.05% ('t' - test) Results in a column followed by the same sign are not significantly different, n = number of adults
◆Based on the observations on the markings on the frons and length of elytra

(Table 2). It was also noticed that there was no significant difference ($P < 0.05$) in size between same sex of the distinguishable and indistinguishable sexes (Table 2).

The study revealed that every adult of *X. quadripes* can not be sexed based on the body size, marking on the face and comparing the length of hind femora with that of elytra as these characters are not consistent in a population. However, all adults of *X. quadripes* can be sexed based on the shape and size of the last segment of the abdomen.

REFERENCES

Anonymous, (1996–97) Annual Report, Coffee Board, Research Department: India, 37.

Hall David, R., Alan Cork, Sara Phythian, Chittamuru Sumathi, Jayarama, Venkatesha, M. G., Violet D'Souza, M. and Naidu, R. (1998) Studies on the male sex pheromone of the coffee white stem borer, *Xylotrechus quadripes* Chevrolat (Coleoptera: Cerambycidae), *2nd International Symposium on Insect Pheromones*. March, 1998. WICC - International Agricultural Center: The Netherlands, 50–52.

Jayarama, and Venkatesha, M. G. (1995) A note on pheromone technology for coffee white stem borer, *Xylotrechus quadripes* (Chevr.) (Coleoptera: Cerambycidae), *Proceedings of Indo-British Workshop on Current Approaches to Pheromone Technology*, November 1995. Madras, 50–51.

Stebbing, E. P. (1914) *Indian forest insects of economic importance*, Government of India: 648.

(Received in January 1999; revised and accepted in June 1999)

Seed Technological Traits among some multivoltine and bivoltine breeds and their hybrids of silkworm, *Bombyx mori* L.

T. K. Narayanaswamy[*1], R. Govindan[1] and S. R. Ananthanarayana[2]

[1]*Department of Sericulture, University of Agricultural Sciences, GKVK, Bangalore 560065, India*
[2]*Department of Sericulture, Bangalore University, Bangalore 560056, India*

ABSTRACT: Grainage traits were studied in seven multivoltine (PM, Thai, $P_2 D_1$, HM, Nistari, KG and KJ) and four bivoltine breeds (NB_4D_2, NB_{18}, KA and NP_2) and their 28 hybrids of silkworm, *Bombyx mori* L. through line × tester analysis. The performance of bivoltine parents was far superior to multivoltines in respect of pupal weight and fecundity while that of multivoltine parents was for rate of pupation and moth emergence. Among hybrids KJ × KA and HM × NB_4D_2 were superior for rate of pupation and moth emergence whereas KG × KA performed better for rate of pupation and fecundity. © 1999 Association for Advancement of Entomology

KEYWORDS: Silkworm, *Bombyx mori*, hybrids

The concept of utilizing silkworm hybrids in commercial cocoon production started during 1922 in Karnataka. The first hybrid that came into vogue was Pure Mysore × C-Nichi (Jolly, 1983). Testing of the multivoltine and bivoltine silkworm breeds for their seed technological traits is essential to identify the best performing ones to involve as parents in any breeding programme. It is a well established fact that the hybrid vigor is obvious among F_1s in silkworm, *B. mori* L. (Das *et al.*, 1994).

The study was carried out at Department of Sericulture, University of Agricultural Sciences, Bangalore during 1997. Each of the seven multivoltine breeds were crossed with all the four bivoltine breeds individually to obtain 28 crosses. Rearing was conducted as per Krishnaswami (1994). Observations were recorded on weight of 10 pupae, rate of pupation, rate of moth emergence based on number of pupae formed and fecundity. The data were analysed as per Snedecor and Cochran (1979).

The mean performance of multivoltine lines, bivoltine testers and their hybrids for seed technological traits is presented in Tables 1 and 2. The line KG (88.67%) was statistically superior to the remaining multivoltines as well as bivoltine parents for rate of pupation. The highest pupation was encountered in KJ × KA (92.0%). Rate

*Corresponding author

TABLE 1. Mean performance of parental silkworm breeds for seed technological traits

Parental breeds	Rate of pupation (%)	Weight of 10 pupae (g)	Rate of moth emergence (%)	Fecundity (No. of eggs/ laying)
PM	79.00	10.56	92.00	529.00
Thai	74.00	7.84	94.00	443.33
P_2D_1	68.33	14.95	97.00	458.67
HM	64.00	11.27	83.00	429.67
Nistari	73.00	11.73	94.33	417.67
Kolar Gold	88.67	10.59	93.00	542.67
Kollegal Jawan	85.00	11.81	96.00	500.33
NB_4D_2	68.00	16.32	95.00	672.67
NB_{18}	64.33	15.06	89.00	609.67
KA	62.00	15.07	77.00	682.67
NP_2	74.00	14.49	93.00	539.67
S. Em ±	1.24	0.47	1.09	21.91
C.D. at 5%	3.44	1.31	3.03	60.73
C.D. at 1%	4.53	1.73	3.98	79.94

of pupation was much prominent among multivoltines than bivoltine parents. These findings are similar to those of Pershad *et al.* (1986) and Banuprakash (1990).

TABLE 2. Mean performance of multivoltine × bivoltine crosses of silkworm for seed technological traits

Silkworm Hybrids	Rate of pupation (%)	Weight of 10 pupae (g)	Rate of moth emergence (%)	Fecundity (No. of eggs/ laying)
1	2	3	4	5
PM × NB_4D_2	88.33	15.77	95.67	594.33
PM × NB_{18}	71.33	14.72	90.00	647.33
PM × KA	57.00	13.34	75.00	481.33
PM × NP_2	70.33	12.19	80.33	480.00
Thai × NB_4D_2	58.00	11.36	93.00	663.00
Thai × NB_{18}	57.33	10.86	85.00	542.00
Thai × KA	65.00	14.90	97.00	637.67
Thai × NP_2	53.67	11.69	95.00	530.00
$P_2D_1 \times NB_4D_2$	53.67	14.32	84.33	691.00
$P_2D_1 \times NB_{18}$	86.67	17.62	93.00	567.00
$P_2D_1 \times KA$	79.33	17.22	93.00	592.33
$P_2D_1 \times NP_2$	59.00	17.97	91.00	541.00

Table 2. *Contd* . . .

I	2	3	4	5
HM $\times$ NB$_4$D$_2$	66.67	15.49	97.00	642.00
HM $\times$ NB$_{18}$	90.67	16.44	90.33	602.00
HM $\times$ KA	63.33	14.46	93.00	649.00
HM $\times$ NP$_2$	59.33	13.50	88.33	532.00
Nistari $\times$ NB$_4$D$_2$	60.67	12.48	96.67	502.00
Nistari $\times$ NB$_{18}$	48.33	12.63	93.00	563.00
Nistari $\times$ KA	50.00	12.35	96.67	503.00
Nistari $\times$ NP$_2$	75.67	15.01	93.00	665.00
K.Gold $\times$ NB$_4$D$_2$	89.33	17.17	90.33	693.67
K.Gold $\times$ NB$_{18}$	79.00	16.06	93.00	637.00
K.Gold $\times$ KA	91.00	15.64	86.00	799.00
K.Gold $\times$ NP$_2$	69.33	14.02	70.00	474.67
K.Jawan $\times$ NB$_4$D$_2$	73.00	15.61	96.00	589.67
K.Jawan $\times$ NB$_{18}$	65.33	14.28	97.00	654.00
K.Jawan $\times$ KA	92.00	16.95	87.00	671.67
K.Jawan $\times$ NP$_2$	51.67	15.04	94.00	735.00
S. Em $\pm$	1.24	0.47	1.09	21.91
C.D. at 5%	3.44	1.31	3.03	60.73
C.D. at 1%	4.53	1.73	3.98	79.94

Pupal weight, the most important trait that contributes for cocoon yield was highest in the hybrid $P_2D_1 \times NP_2$ (17.97 g/10 pupae). It ranged from 10.86 (Thai $\times$ NB$_{18}$) to 17.97 g ($P_2D_1 \times NP_2$) among hybrids. These observations are on parity with the findings of Udupa (1986) and Banuprakash (1990).

The highest rate of moth emergence (97%) was registered by P_2D_1 and among hybrids the same was highest in Thai $\times$ KA, HM $\times$ NB$_4$D$_2$ and KJ $\times$ KA (97%). Similar trend was observed by Udupa (1986) and Banuprakash (1990).

Fecundity was highest among bivoltine parental breeds than multivoltines and this may be attributed to higher pupal weight and genetic architecture among the former. It was highest of 799(KG $\times$ KA) among hybrids and the higher pupal weight of KA might have also contributed for it.

The performance of bivoltine silkworm breeds in respect of different grainage traits was superior for pupal weight and fecundity and that of multivoltine breeds for rate of pupation and moth emergence. Among hybrids, KJ $\times$ KA, KG $\times$ KA and HM $\times$ NB$_4$D$_2$ were superior for seed technological traits. Hence, it is inferred that these hybrids may be further utilised in future breeding programmes concerning to improvement of seed technological traits.

REFERENCES

Banuprakash, K. G. (1990) Heterosis and line x tester analysis in multivoltine and bivoltine races of silkworm *Bombyx mori* L. M. Sc. (Seri.) Thesis, UAS, Bangalore, 177.

Das, S. K., Pattnaik, S., Ghosh, B., Nair, B. P., Sen, S. K. and Subbarao, G. (1994) Heterosis analysis in some three way crosses of *Bombyx mori* L., *Sericologia* **34**: 51–61.

Jolly, M. S. (1983) Lead paper : Silkworm Genetics and Breeding, *Natl. Semi. Silk Res. & Dev.,* C.S.B : Bangalore, 19.

Krishnaswami, S. (1994) *A Practical Guide to Mulberry Silk Cocoon Production in Tropics,* Sreeramula Consultants: Bangalore, 47–94.

Pershad, G. D., Datta, R. K., Vijayakumar, H. V., Bhargava, S. K. and Jolly, M. S. (1986) Performance of some multivoltine races of *Bombyx mori* L., *Sericologia* **26**: 295–301.

Snedecor, G. W. and Cochran, N. G. (1979) *Statistical Methods,* Iowa State University Press: Ames, Aowa, 593.

Udupa, S. M. (1986) Heterosis in relation to single, three way and double cross hybrids of selected races of silkworm *Bombyx mori* L. M.Sc. (Agri.) Thesis, UAS, Bangalore, 127.

Field Parasitization of Sugarcane Internode Borer by Egg Parasitoid *Telenomus beneficiens* Zehnt

B. Rajendran

Associate Professor of Entomology, Sugarcane Research Station (Tamil Nadu Agricultural University), Cuddalore 607001, Tamil Nadu, India

ABSTRACT: Sugarcane internode borer, *Chilo sacchariphagus indicus* (Kapur) an economically important pest is naturally parasitized by the scelionid parasitoid, *Telenomus beneficiens* Zehnt. under field conditions in Cuddalore region of Tamil Nadu. The egg parasitoid *T. beneficiens* was more prevalent during September to March of 1997 and 1998 from 32.3 to 73.5 per cent. Though not amenable for mass rearing under laboratory conditions, this parasitoid is found to afford moderate natural check on the internode borer of sugarcane in field.
© 1999 Association for Advancement of Entomology

KEYWORDS: Internode borer, sugarcane, *Telenomus beneficiens*

Sugarcane internode borer, *Chilo sacchariphagus indicus (Kapur)* (Crambidae: Lepidoptera) is one of the important pest affecting cane yield and sugar recovery in India (David, 1981; Nandagopal, 1983). Among the natural enemies recorded on this pest, the parasitoids viz. *Trichogramma chilonis* Ishii. (Trichogrammatidae: Hymenoptera) and *Telenomus beneficiens* Zehnt. (Scelionidae: Hymenoptera) were reported to be more potent (Varatharajan *et al.*, 1971). Hence, inorder to assess the extent of egg parasitization of *T. beneficiens*, observations were carried out in Sugarcane Research Station, Cuddalore, Tamil Nadu during 1996 to 1998.

Field observations on internode borer egg parasitization was made from April 1996 to March 1998. Five different fields of one acre each was selected and eggs of internode borer was collected in each field at fortnightly intervals. The percentage egg parasitization was calculated by counting the total eggs Vs parasitized eggs. The parasitized eggs were then observed for the confirmation of emergence of *T. beneficiens* adults. The mean data was pooled monthwise separately for each season and the percentage parasitization is presented in the form of bar diagrams (Fig. 1).

The egg parasitoid, *T. beneficiens* was found to be more predominant from September to March (32.3 to 73.5%) both years, when the crop was in active vegetative phase to maturity, a period highly prone to the attack of internode borer. During November, 1997 and 1998, the parasitization was reduced to 12.5 and 17.0 per cent respectively which might be due to the onset of peak north-east monsoon in this region. During April and May, the incidence was only stray due to the harvest of
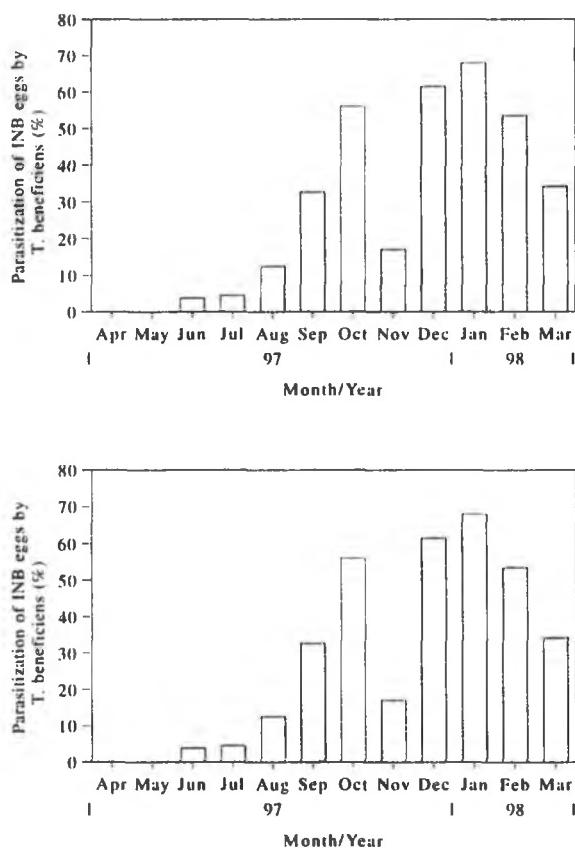
FIGURE I.

the crop. The months from June to August also had recorded lesser parasitization by *T. beneficiens* (2.25 to 12.5%) because of the non-conducive stage (tillering phase to early vegetative phase) of the sugarcane crop for internode borer attack. This study revealed that the naturally prevalent egg parasitoid *T. beneficiens* even to the extent of 73.5 per cent in field and along with the inundatively released parasitoid *Trichogramma chilonis*, will act as a powerful biocontrol strategy against internode borer of sugarcane.

REFERENCES

David, H. (1981) Current research on sugarcane internode borer, *Chilo sacchariphagus indicus* (Kapur) and its control, *Proceedings of the National Symposium on Stalk borer, Karnal*, 117– 121.

Nandagopal, V. (1983) Studies on yield loss assessment and determination of economic thresh-
   old for sugarcane internode borer, *Chilo sacchariphagus indicus (K). M. Sc(Ag.) Thesis*,
   Tamil Nadu Agricultural University, Coimbatore, 157.
Varatharajan, G., Saivaraj, K. and Raghavan, S. (1971) A note on egg parasites of sugarcane
   borers at Cuddalore, *Indian Sugar* **21**: 433–434.

Effect of Temperature on the Activity of Alkaline Proteases in the Midgut Tissue and Haemolymh of the Silkworm, *Bombyx mori* L.

C. D. Basavaraju, B. Lakshmi Kumari and S. R. Ananthanarayana*

Department of Studies in Sericulture, Bangalore University, Jnanabharathi campus, Bangalore 560056, India

ABSTRACT: The polyvoltine (C-nichi) and bivoltine (KA) strains of *Bombyx mori* were subjected to two different temperatures viz. $33 \pm 1\,°C$ and $25 \pm 1\,°C$. The activity of alkaline proteases in haemolymh and midgut tissue of IV and V stadium larvae was studied. The period of larval life was shorter when reared at $33\,°C$. The peak activity of proteases was observed in the beginning of each instar at $33\,°C$, whereas in larvae at $25\,°C$ the peak activity was in the middle part of the each instar. It is concluded that temperature had effected the metabolic activities of the larvae and protease activity was more in larvae reared at $33\,°C$ than at $25\,°C$.
© 1999 Association for Advancement of Entomology

KEYWORDS: Alkaline protease, temperature, midgut, haemolymph, *Bombyx mori*

INTRODUCTION

Proteolytic enzymes of the alimentary canal in insects including *Bombyx mori* were investigated from the view point of nutrition and enzymology by many investigators (Law *et al.*, 1977; Eguchi *et al.*, 1982; Eguchi and Arai, 1983).

Eguchi and Iwamoto (1982) have shown that the midgut protease in silkworms is a trypsin like enzyme. Chatterjee *et al.* (1989) studied the protease activity in the digestive juice of different breeds of mulberry silkworm.

However, very little is known about the influence of temperature on total protease activity during IV and V instar development. Since utilization of exogenous proteins is an important factor for growth and development of the larva in insects (Chen, 1978), the proteolytic activity might reflect the physiological status of the worm in different voltinism.

*Corresponding author
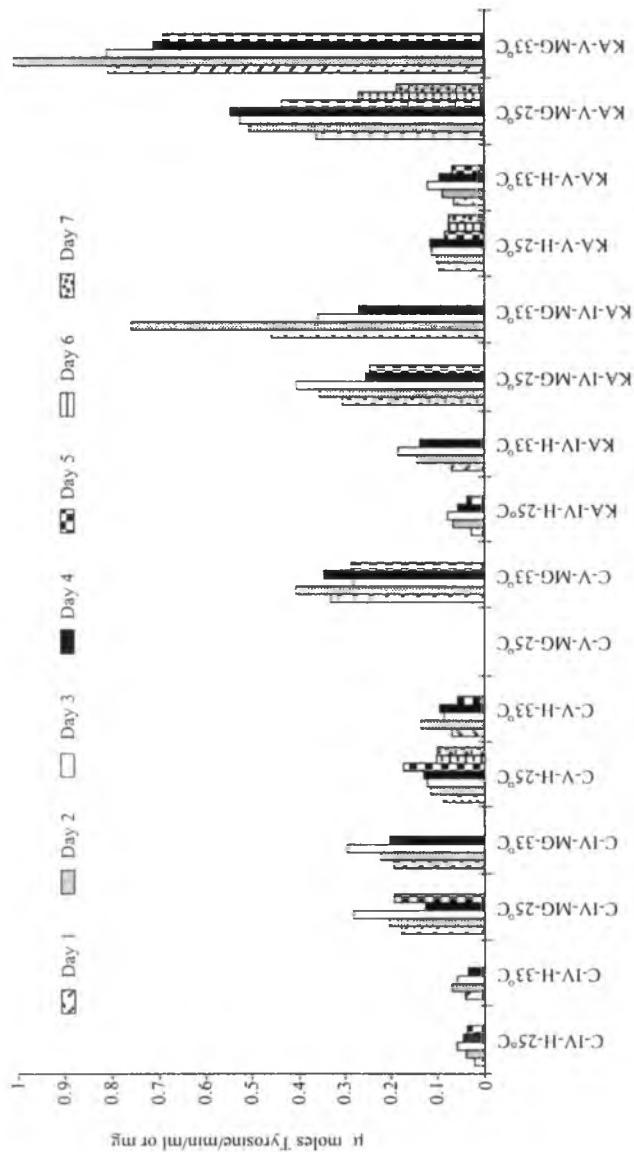
FIGURE 1. Histogram showing effect of temperature on the activity of protease in different races of *Bombyx mori*; abbreviations used: C = C-nichi race; KA = KA race; IV = IV stadium larvae; V = V stadium larvae; H = Haemolymph; MG = Midgut.

The silkworm strains used for the present study included, C-nichi (polyvoltine) and KA (bivoltine). They were reared at 33 ± 1 °C and 25 ± 1 °C of temperature and relative humidity of 80%. The rearing conditions and temperature treatment were similar to the method followed earlier (Basavaraju *et al.*, 1996).

Haemolymph and midgut tissue were collected every day from the 1st day of the IV instar upto the onset of spinning. Haemolymph was collected in precooled 5 ml. tubes containing few crystals of phenyl thiourea. The midgut was separated from the rest of the alimentary tract, flushed with ice-cold *Bombyx* saline to make free of leaf debris and stored in crushed ice (Yamaoka *et al.*, 1971). A 10% (w/v) homogenate of the midgut tissue was prepared according to the method of Eguchi and Arai (1983).

Both haemolymph and midgut tissue homogenate samples were centrifuged at 3000 rpm for 10 mins. to remove haemocytes and tissue residue respectively and stored at - 20 °C until use.

Determination of protease activity

The protease activity was assayed following the method of Eguchi and Iwamoto (1976) and the values are expressed as μ moles of tyrosine liberated/min/mg and μ moles of tyrosine liberated/min/ml. for midgut tissue and haemolymph respectively. The protease activity observed in haemolymph and midgut tissue of IV and V stadium larvae of C-nichi and KA races reared at 25 °C and 33 °C is presented in Fig. 1.

In C-nichi strain, the maximum protease activity in both haemolymph and midgut tissues of IV instar was observed when reared at 33 °C compared to the larvae reared at 25 °C. The peak activity was on 3rd day at 25 °C and on 2nd (haemolymph) or 3rd day (midgut) at 33 °C. However, during V instar from 3rd day onwards the maximum activity of protease was at 25 °C. The peak activity was on 2nd day at 33 °C and on 4th (midgut) or 5th day (haemolymph) at 25 °C.

In KA strain, during IV instar the protease activity was maximum at 33 °C in both haemolymph and midgut. However in midgut tissue at 33 °C during 3rd day of IV instar, the protease activity was slightly less compared to larvae at 25 °C. The peak activity was noticed on 2nd (midgut) or 3rd day (haemolymph) at 33 °C and on 4th day in larvae at 25 °C. During V instar, the midgut tissue at 33 °C showed maximum protease activity throughout the period. But, in haemolymph, the protease activity was more at 25 °C except on 3rd day of development.

The present results are in agreement with the previous report (Upadhyay, 1983) states that the activity of protease increases with increase of temperature. This may be due to the fact that high consumption of food and fast movement of food through the gut at higher temperature activates the digestive enzymes. Upadhyay and Mishra (1994) determined the effect of temperature variation on the movement through the gut and egestion of excretory pellet of *B. mori* larvae.

In the present investigation, the larval period was reduced by one day during IV instar and by two days during V instar at high temperature (33 °C) in both the strains (C-nichi and KA). These results clearly depicts that the high rearing temperature caused the physiological upset as stated earlier by Benchamin and Nagaraj

(1987). The present results are further confirmed by the observations of Upadhyay and Mishra (1991) on nutritional ability of bivoltine silkworm larvae at high temperature regimes.

The results of the present investigation clearly shows maximum activity of protease in midgut tissue when compared with haemolymph. Since the midgut tissue is the chief site for the secretion of proteolytic enzyme, maximum enzyme activity in the midgut is noticed. However, the haemolymph is the only carrier of all the necessary substances including enzymes, the low protease activity in the haemolymph is justified.

ACKNOWLEDGEMENTS

REFERENCES

Basavaraju, C. D., Lakshmi Kumari, B. and Ananthanarayana, S. R. (1996) Effect of temperature on the activity of amylase in silkworm *Bombyx mori* L., *Entomon* 21(2): 171–176.

Benchamin, K. V. and Nagaraj, C. S. (1987) Silkworm rearing techniques, In: *Appropriate sericulture techniques*, Jolly, M. S.: (Editor). International Centre for training and Research in Tropical Sericulture: Mysore, India, 73–78.

Chatterjee, G. K., Rao, G. P., Aswath, S. K. and Chatterjee, S. N. (1989) Studies on the protease activity in the digestive juice of different breeds/races of mulbery silkworm *Bombyx mori*, *Newsletter* 4(3): 6–7.

Chen, P. S. (1978) Regulation of proteolytic enzymes, In: *Insect physiology*, Rockstein, M.: (Editor). Academic Press: New York, 162–168.

Eguchi, M. and Arai, M. (1983) Relationship between alkaline proteases from the midgut lumen and epithelia of the silkworm: solubilisation and activation of epithelial protease (6B3), *Comp. Biochem. Physiol.* 75B: 589–593.

Eguchi, M. and Iwamoto, A. (1976) Alkaline protease in the midgut tissue and digestive fluid of the silkworm *Bombyx mori*, *Insect Biochem.* 6: 491–496.

Eguchi, M. and Iwamoto, A. (1982) Comparison of three alkaline proteases from digestive fluid of the silkworm *Bombyx mori* L., *Comp. Biochem. Physiol.* 71B: 663–668.

Eguchi, M., Iwamoto, A. and Yamauchi, K. (1982) Interrelation of proteases from the midgut lumen, epithelia and peritrophic membrane of the silkworm *Bombyx mori* L., *Comp. Biochem. Physiol.* 72A: 359–363.

Law, J. H., Dunn, P. F. and Kramer, K. J. (1977) Insect proteases and peptidases, *Adv. Enzymol.* 45: 389–425.

Upadhyay, V. B. (1983) Movement of food through the gut of *Catharsius molossus* (Coleoptera: Scarabaeidae), *Acta Physiol. Hung.* 61(3): 185–189.

Upadhyay, V. B. and Mishra, A. B. (1991) Nutritional ability of bivoltine silkworm, *Bombyx mori* L. larvae at higher temperature regimes, *J. Adv. Zool.* 12(1): 56–59.

Upadhyay, V. B. and Mishra, A. B. (1994) Influence of temperature on the passage of food through the gut of multivoltine *Bombyx mori* L. larvae, *Indian J. Seric.* 33(2): 183–185.

Yamaoka, K., Hashino, M. and Hirao, T. (1971) Role of sensory hairs on the anal papillae on oviposition behaviour of *Bombyx mori*, *J. Insect Physiol.* 17: 897–911.

Effect of Temperature and Female Age on the Development and Progeny Production of *Cryptolaemus montrouzieri* Mulsant (Coleoptera: Coccinellidae)

S. K. Jalali*, S. P. Singh and S. R. Biswas

*Project Directorate of Biological Control, Post Bag No. 2491, H. A. Farm Post,
Bellary Road, Bangalore 560024, India
Email: pdblc@kar.nic.in*

ABSTRACT: Effect of temperature and female age on the development, progeny production, longevity and mortality of *Cryptolaemus montrouzieri* Mulsant was studied in the laboratory. Temperature ranges between 25° and 30 °C were most ideal for development, and progeny production of the predator. *C. montrouzieri* could produce sizable progeny even when it was deprived of the host mealybug *Maconellicoccus hirsutus* (Green) for 15 days. Regression analysis revealed significant relationship between various parameters viz. developmental time, fecundity and longevity with temperature with R^2 being 0.82, 0.98, and 0.91 and between parameters like mortality, developmental time, and fecundity with female age with R^2 being 0.92, 0.92 and 0.91, respectively. © 1999 Association for Advancement of Entomology

KEYWORDS: *Cryptolaemus montrouzieri*, temperature, female age

Temperature (T), maternal age (MA) and host deprivation (HD) controls the increase in numbers for many insect species. Such influences have been proved for few insects species such as *Brachymeria intermedia* (Nees), *Cheilomenes sexmaculata* (Fabricius) and *Chilocorus* spp. (Podoler and Henen, 1983; Barbosa *et al.*, 1986; Alikhan and Yousuf, 1986). No attempt has been made to study T, and MA and HD effect in *Cryptolaemus montrouzieri* Mulsant, therefore, the present study was conducted to work out its consequence on development, fecundity and longevity of *C. montrouzieri*, which is most important exotic predator of mealybugs in India. Such study will be valuable to know biological trait when stresses are forced upon this predator.

Maconellicoccus hirsutus was reared on the pumpkin fruits (*Cucurbita moschata* Duch.) and was utilised to rear *C. montrouzieri* in the laboratory. In temperature (T) studies, 10 pairs of freshly emerged predators were released on mealybug infested pumpkin fruits inside rearing cage 30 cm^3 and were kept in BOD incubators maintained at 15, 20, 25, 30, and 35 °C. Observations were recorded on preoviposition period,

*Corresponding author

TABLE 1. Effect of different temperatures on biological attributes of *Cryptolaemus montrouzieri*

Temperature (°C)	Preoviposition period (in days)	Developmental time (in days)	Fecundity (No. of eggs/♀)	Longevity of females (in days)
15	90.0[a]	0.0[a]	0.0[a]	90.0[a]
20	18.3[b]	32.0[c]	80.3[c]	83.0[a]
25	6.3[c]	29.3[c]	103.6[d]	77.6[b]
30	6.3[c]	29.3[c]	108.0[d]	32.0[c]
35	7.3[c]	24.0[b]	30.3[b]	17.6[d]

* means followed by same letters are not different significantly ($P = 0.05$)

S. Em.	1.08	1.04	2.60	1.64
C. D.	3.53	3.40	8.47	5.35
F-test	**	**	**	**

development of immature stages, and fecundity and longevity until all adults died. Experiment was replicated 3 times at each temperature with 10 pairs in each replication.

In second experiment on maternal age (MA) and host deprivation (HD), 10 pairs of adults for each period were kept in plastic container (15×10 cm) at room temperature (26 ± 1.5 °C) and RH 55–60% for 5, 10, 15, 20, 25, and 30 days without host mealybug. Adults were provided with honey +agar as food. After each period, mortality was recorded and 10 pairs or surviving adults were transferred on mealybug infested pumpkin as done in T experiment. Same type of observations were recorded as in T experiment.

The experiment design was factorial CRD with a predator, 5 T ranges and 6 different MA groups, and 3 replications. ANOVA was carried out for testing significant difference among T, and MA groups for different biological parameters like preoviposition period, development time, fecundity, longevity and adult mortality.

Regression analysis was carried out using the quadratic power curve $Y = a + b_1 x + b_2 x^2$, where the development variable Y = development time, fecundity, and longevity for T response, and Y = mortality, development time and fecundity for MA response and the independent variable $x = T$, and MA and HD, respectively.

In the experiment on temperature (T) effect, adults did not lay any egg at 15 °C though they remained alive for 90 days, At 20 °C, preoviposition period was extended by 3 folds comparing temperatures between 25 to 35 °C. Developmental period of grubs was shortest at 35 °C and there was non-significant difference at T between 20 and 30°C. Fecundity of adults was greately affected by lower and higher T. Thus T between 20 and 30 °C was found to be ideal as progeny production increased by 3.5 folds. Similarly longevity was also greatest between these two T ranges (Table 1). Babu and Azam (1987) have earlier reported 30 °C as optimum constant T for *C. montrouzieri*. In present study, preoviposition period was reduced from 18 to 6 days when T was increased from 20 to 30 °C and developmental period of grubs was

TABLE 2. Effect of material age of *C. montrouzieri* female on mortality and reproduction

Female age (in days)	Mortality (%)	Preoviposition period (in days)	Developmental time (in days)	Longevity of females (in days)	Fecundity of females (in days)
5	0.0[a]	6.0[a]	29.0[a]	43.3[a]	91.0[a]
10	0.0[a]	6.3[a]	29.0[a]	39.0[b]	94.3[a]
15	6.0[a]	6.6[a]	30.0[a]	23.0[c]	90.0[a]
20	68.0[b]	8.6[ab]	31.6[a]	19.0[c]	39.0[b]
25	82.0[c]	10.0[b]	33.0[a]	12.0[d]	13.3[c]
30	98.0[d]	19.0[c]	33.6[a]	3.3[e]	1.6[d]
* means followed by same letter are not significantly different ($P = 0.05$)					
S. Em.	1.91	0.67	0.84	2.02	2.37
C. D at 5%	6.02	2.12	-	6.37	7.47
t-test	**	**	NS	**	**

directly related to temperature. Podoler and Henen (1983) reported that *Chilocorus kuwanae* Silv. developed faster between 18 and 22 °C and it could not complete development at 32 °C. In present study though development of grubs was shortest at 35 °C but fecundity and longevity was greatly affected. Earlier Babu and Azam (1987) for *C. montrouzieri* and Alikhan and Yousuf (1986) for *C. sexmaculata* reported that adults laid highest number of eggs at 30 °C, their findings are corroborated in the present study.

Maternal age (MA) and host deprivation (HD) effect suggest that there was negligible mortality up to 15 days of female age. Mortality increased from 68.0 to 98.0 per cent with increase in MA and HD from 20 to 30 days. Preoviposition period was extended by 2.0 to 12.4 days if MA and HD were beyond 20 days. Age of the female had non-significant effect on development of grubs ($P = 0.05$). It ranged from 29.0 to 33.6 days (Table 2). However, Mousseau and Dingle (1991) reported that *Oncopeltis cingulifer* Stål offsprings born of female ($<$ 50 days old) take about 28 days to develop, while offsprings of female ($>$ 65 days old) take only 25 days. Fecundity was drastically affected by age of the female as five to fifteen days old female produced greater progeny (Table 2). Reduction in fecundity and longevity due to HD and MA has been reported by Navasero and Elzen (1992) for braconid parasitoid, *Microplits croceipes* (Cresson) and by Barbosa *et al.* (1986) for chalcid parasitoid, *Brachymeria intermedia* (Nees).

The regression curve presented by $Y = a + b_1 x + b_2 x^2$, in T response prediction model on parameters like developmental time, fecundity and longevity showed significant relationship with T with R^2 of 0.82, 0.98, and 0.91, respectively. In MA prediction model, parameters like mortality, developmental time and fecundity also indicated significant relationship with MA with R^2 of 0.90, 0.92, and 0.91, respectively (Table 3). The present study, therefore, identifies temperature between

TABLE 3. The regression equations for temperature and female age
response in *Cryptolaemus montrouzieri*

Y	$Y = a + b_1 x + b_2 x^2$				
	a	b_1	b_2	R^2	F-Cal
Temperature response					
Developmental time	−119.30	11.04	0.20	0.82	4.680
Fecundity	−523.57	48.99	−0.94	0.98	41.907
Longevity	228.49	0.1239	0.18	0.91	10.067
Female age response					
Mortality	−18.8	1.76	0.08	0.90	14.025
Developmental time	27.6	0.19	0.001	0.92	16.670
Fecundity	102.0	−0.18	−0.12	0.91	15.127

25 and 30 °C as ideal for predator multiplication and in absence of host, female can
retain its biotic potential for 15 days.

ACKNOWLEDGEMENT

REFERENCES

Alikhan, M. A. and Yousuf, M. (1986) Temperature and food requirement of *Cheilomenes sex-maculata* (Coleoptera: Coccinellidae), *Environ. Entomol.* **15**: 800–802.

Babu, T. R. and Azam, K. M. (1987) Biology of *Cryptolaemus montrouzieri* Mulsant (Coccinellidae: Coleoptera) in relation with temperature, *Entomophaga* **32**: 381–386.

Barbosa, P., Martinat, P. and Bennett, R. (1986) Consequences of maternal age and host deprivation on the production and development of *Brachymeria intermedia* (Nees) and the mortality of its gypsy moth (*Lymantria dispar* L.) host, *J. Appl. Entomol.* **101**: 215–223.

Mousseau, T. A. and Dingle, H. (1991) Maternal effect in insect life histories, *Annu. Rev. Entomol.* **36**: 511–534.

Navasero, R. and Elzen, G. (1992) Influence of maternal age and host deprivation of egg production and parasitisation by *Micropletis croceipes* (Hymenoptera: Braconidae), *Entomophaga* **37**: 37–44.

Podoler, H. and Henen, J. (1983) A comparative study of the effects of constant temperatures on development time and survival of two coccinellid beetles of the genus *Chilocorus*, *Phytoparasitica* **11**: 167–176.

Book Review

Assassin Bugs, By Dunstan P. Ambrose
Science Publishers, Inc. USA, 1999, 334 Pages

Increasing interest in the reduviid bugs or assassin bugs has been evident in recent years in view of their potential as useful predators. With his enviable background, the author has chosen to provide a more or less comprehensive account of the group, more with a view to enable interested student to become acquainted with the diverse aspects of the biosystematics, ecology and behaviour of this group of insects.

The seven major sections involving biosystematics, ecology, biology structure and function, behaviour economic importance and physiology, have been further subdivided with several small chapters in order to provide the student with some information on various aspects of the complexities involved. However, at a time when increased referance is associated to biosystematics, the need for a more incisive approach to this aspect cannot be overemphasised. The author's ability to identify several species belonging to diverse subfamilies should enable him to provide increased stres in this area, so that prospects of increased ability of this group should be forthcoming.

It may also be mentioned that areas such as neuroendocrine system, egg, chromosomes, haemolyemph have received minimal attention, perhaps serving as an indicator for the need for more involvement in these areas in future. Judging from the overall point of view it has to be indicated that this is a praiseworthy attempt by the author whose inimitable interest in this group has led him to adopt a more comprehensive picture, mostly based on work done by him and his students. I have no hesitation that this book would stimulate further interest in the reduviids enabling more realistic utilization in the biological control of insects.

Dated 28.9.1999.

T. N. Ananthakrishnan
Flat 6, Dwaraka, 22, Kamdar Nagar
Nungambakkam, Chennai-600034.

ENTOMOCONGRESS 2000
Perspectives for the new Millennium

An International Conference to be organized by the Association for Advancement of Entomology (AAE) during the Silver Jubilee year 2000 of AAE and its Journal ENTOMON from November 5–8 at Trivandrum, the capital city of Kerala state of Indian peninsula. Major themes of the Conference cover most of the emerging areas of Entomological Science *viz.*: **Concepts and Strategies of Insect Pest Management; Physiology and Molecular Biology; Ecology, Behavior and Insect-Host Interactions; Taxonomy, Biodiversity and Evolution**. Invited speakers will review progress in different fields of Entomology in Plenary Lectures apart from oral and poster presentations and meetings of specialized groups during the 3 day Congress.

Contact: Dr. D. Muraleedharan,
            Organizing Secretary, Entomocongress 2000
            Department of Zoology, University of Kerala,
            Kariavattom-695581, Trivandrum, India.
            Tel: 91-471-418906
                91-471-447712
            E-mail:dmur@md3.vsnl.net.in

AUTHOR INDEX

Reg. No. 123SBN